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VOLUME I. INTRODUCTION.

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DEPARTMENT OF THE ARMY
US ARMY TRADOC SYSTEMS ANALYSIS ACTIVITY
WHITE SANDS MISSILE RANGE
NEW MEXICO 88002

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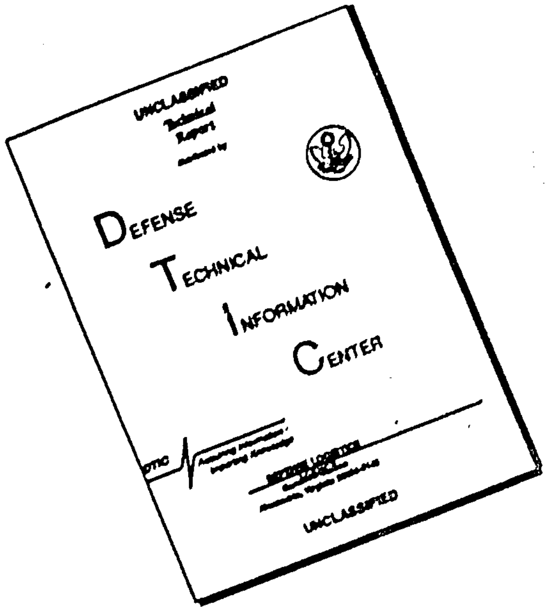

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TRASANA

TECHNICAL REPORT NO. 3-78

FLIGHT PROFILE PERFORMANCE HANDBOOK

VOLUME I - INTRODUCTION

PREPARED BY

Nathan H. Cleek, Jr.
Edward F. Smith, Jr.
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MAY 1978

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CHAPTER 1

INTRODUCTION

1. PURPOSE

The purpose for preparing this handbook series is fourfold: (a) to validate performance data quickly, (b) to reduce the manpower and time to prepare accurate flight profiles, (c) to standardize performance data so that the analysis community can benefit from a single reference in conducting studies and (d) to provide a handbook that can be used for training in the mission profile planning area.

2. BACKGROUND

The data contained in this Flight Profile Performance Handbook (FPPH) series was originally acquired as a data base for the Aircraft Mission Processing Simulation (AMPS) model. AMPS is a computer program developed by the Aviation Systems Analysis Branch of the US Army TRADOC Systems Analysis Activity (TRASANA) to support Cost and Operational Effectiveness Analyses (COEAs). AMPS generates detailed flight profiles for a wide variety of helicopter missions. The data was provided TRASANA by the Army Aviation Research and Development Command (AVRADCOM) and was the most accurate data available to AAVRADCOM at the time of handbook publication. In structuring the data base for AMPS it was noted that the data, when properly organized, could provide a method of doing quick and simple flight profile simulations. This volume contains an overview of the other volumes, explains how the data was analyzed, how it is presented and how it can be used.

3. OBJECTIVES OF THE HANDBOOK

a. Data Validation. The other volumes of this handbook series, one for each A/C, contain tables with the precise performance data and format required to develop flight profiles for computer simulations. Using the handbooks as a reference, the individual project manager (PM) will be able to quickly validate or update as required all associated data contained in the different tables. If this procedure is followed by the various PMs, support of Helicopter COEAs and other analyses can be efficiently implemented.

b. Flight Profile Development. Much of the manpower and time spent in preparing flight profiles for supporting aircraft COEAs is dedicated to look-up, correlation and validation of performance data. Once the procedure contained in this handbook is implemented, flight profiles can be easily prepared. What normally took one man 4 to 5 days to prepare can now be prepared in 3 to 4 hours.

c. Standardization of Performance Data. Each of the PMs has been contacted by AVRADCOM to validate the performance data contained in each handbook in this series. Once each handbook is published, the data contained will be kept current as of the publication data. Since the requests for current information are constantly being forwarded to the PMs by analysis groups, this handbook can be a reference and assure a commonality in studies within the community.

d. Training for Planning Missions and Flight Profiles. For training purposes each handbook can stand alone. It is only a matter of following the example provided and applying the proper data to fit the flight profile desired. Although the example shown is simplistic, the methodology may be expanded to apply to any flight profile, no matter how complex.

4. OTHER VOLUMES

This handbook is the first of a series that covers the helicopters in the US Army inventory. The complete set of handbooks and their subjects are:

Volume I - FPPH Description

Volume II - UH-60A (BLACKHAWK)

Volume III - AH-1G (COBRA)

Volume IV - AH-1S (COBRA)

Volume V - YAH-64 (Advanced Attack Helicopter [AAH])

Volume VI - OH-58C (KIOWA)

Volume VII - CH-47 (CHINOOK)

Volume VIII - CH-54 (TARHE)

Volume IX - UH-1H (HUEY)

5. GENERAL HANDBOOK DESCRIPTION

a. Performance Data. The data contained in these volumes is performance data compiled from the results of actual experiments. It is not engineering data and is not intended to serve as a base for future helicopter construction or acquisition. The more mature a particular helicopter is, the less likely there will be a change in the basic performance data.

b. Handbook Organization. This volume is the first of a series of volumes as identified in paragraph 4 above. Volume I is a description of the methodology used to develop the tables for each of the other volumes. All other volumes follow a similar format. Chapter 1 is an introduction followed by the development of a simplified flight profile example in Chapter 2. Chapter 3 provides an explanation of each of the five types of data tables contained in the handbook. The five types of tables deal with: (1) Basic Fuel Flow Data, (2) Delta Fuel Flow for Drag Data, (3) Ground Idle Fuel Flow Data, (4) Gross Weight Limits Data and (5) Velocity Limits Data. Chapter 4 contains the actual tables to be used for developing flight profiles.

CHAPTER 2

PERFORMANCE DATA TABLE DESCRIPTIONS

1. GENERAL

This chapter provides examples of the data and calculations necessary to develop a mission flight profile. The five types of tables, Basic, Drag, Idle, Gross Weight, and Velocity are discussed in detail in the following paragraphs.

2. BASIC FUEL FLOW DATA

a. The basic rate of fuel flow is determined by five variables:

(1) Type of aircraft

(2) Altitude (air pressure)*

(3) Temperature**

(4) Gross weight***

(5) Flight mode

b. Tables 2-1 through 2-4 are examples of basic fuel flow taken from Volume II, BLACKHAWK. The first two variables, listed above, are held constant and appear in the heading of each table, i.e., (1) type of aircraft and (2) altitude. The third variable, (3) temperature is different for each table in the set (-25°C, -5°C, 15°C and 35°C). This factor also appears in the table heading.

c. This combination of altitude (sea level, 2000', 4000', 6000', 8000', and 10,000') and temperature (-25°C, -5°C, 15°C and 35°C) produces 24 tables of basic fuel flow for each aircraft.

d. Each table displays the fuel flow rate in lbs/hr, depending on gross weight and flight mode.

e. For the BLACKHAWK helicopter the tables contain five fixed rows corresponding to gross weights: 12,000 lbs, 14,000 lbs, 16,000 lbs, 18,000 lbs, and 20,000 lbs. Tables for other helicopters may have a different number of rows for different gross weights, but the rows for fuel flow tables will always be fixed gross weights.

---

*All altitudes or air pressures are feet above sea level.

**For simplicity, all temperatures are considered to be the average temperature in which the helicopter is operating (Degrees Centigrade).

***Total vehicle weight in pounds.

f. The ten fuel flow columns are for fixed flight modes. The first column is Hover In Ground Effect (HIGE). For practical use of this handbook each helicopter will have a maximum height at which HIGE is applied. For example, the BLACKHAWK examples used in this volume have a maximum height of 2 feet.

g. The second column is Hover Out of Ground Effect (HOGE). This is any hover above the maximum HIGE height.

h. The third column is Nap of the Earth (NOE). This is defined as flight from 0 to 40 kts with varying altitudes.

i. The remaining columns are for given airspeeds* (in kts) as the flight mode. The BLACKHAWK tables have seven listed airspeeds (in the range from 40 kts to 160 kts). The tables for other helicopters may vary in number of columns but the first three columns are always HIGE, HOGE and NOE while the remaining rows are for the listed airspeeds.

j. The basic fuel flow data** is the major information used from the table in simulating a flight profile. For example, assume a pilot's flight path calls for 30 minutes of flight at 80 kts airspeed, 2000 ft. altitude, 15°C and a gross weight of 18,000 lbs in a UH-60A helicopter. The table labeled: BLACKHAWK, Pressure: 2000 ft, Temperature: 15°C, (Table 2-3), shows that the helicopter will use 739 lbs/hr of fuel. So, for 1/2 hour, 370 lbs will be used.

k. If the helicopter's gross weight was 17,000 lbs instead of 18,000, 17,000 lbs could not be directly read from the table. But by finding 16,000 lbs - 696 lbs/hr and 18,000 lbs - 739 lbs/hr, and interpolating*** between these values, the basic fuel flow rate for 17,000 lbs can be determined as 718 lbs/hr. In this example, for 30 minutes, 359 lbs of fuel would be used.

l. As altitude and/or temperature changes occur, different tables are used to look up the aircraft's basic fuel flow rate for each leg of the flight path. It is also possible to interpolate between tables. In the original example suppose the gross weight is changed back to 18,000 lbs and the temperature is changed to 25°C. There is no table labled BLACKHAWK Pressure 2000 ft, Temperature 25°C. To find the 25°C fuel flow rate two tables are used since 25°C falls between Table 2-3 and Table 2-4. The fuel flow rate at 15°C is 739 lbs/hr and the fuel flow rate at 35°C is 751 lbs/hr. (The intersection of Gross Weight; 18,000 lbs and Airspeed 80 kts on both tables.) Thus interpolation between 739 lbs/hr (15°C) and 751 lbs/hr (35°C) gives a fuel flow rate of 745 lbs/hr (25°C).

**All references to airspeeds are to true airspeeds.*

***The basic fuel flow data represents a clean drag configuration with all doors closed, no wing stores, and no external sling loads.*

****All references to interpolation are linear interpolations.*

TABLE 2-1

BASIC FUEL FLOW

FUEL FLOW RATES FOR THE GIVEN CONDITIONS IN LBS/HR

PRESSURE: 2000 FT   TEMPERATURE: -25 C

AIRCRAFT - UH-60A
BLACKHAWK

GROSS WEIGHTS (LBS)	FLIGHT MODE (KTS)									
	HIGE	HOGE	NOE	40	60	80	100	120	140	160
12,000	637	758	694	630	601	620	682	794	962	1355
14,000	695	853	765	678	639	651	710	817	988	1401
16,000	759	958	845	732	683	686	742	847	1029	1467
18,000	829	1072	933	795	733	725	780	885	1085	1557
20,000	905	1201	1034	866	788	770	824	929	1153	1677

TABLE 2-2

BASIC FUEL FLOW

FUEL FLOW RATES FOR THE GIVEN CONDITIONS IN LBS/HR

PRESSURE: 2000 FT TEMPERATURE: -5 C

AIRCRAFT - UH-60A
BLACKHAWK

GROSS WEIGHTS (LBS)	FLIGHT MODE (KTS)									
	HIGE	HOGE	NOE	40	60	80	100	120	140	160
12,000	653	779	711	643	611	623	673	766	907	1213
14,000	713	878	785	693	650	654	701	790	932	1244
16,000	779	985	868	750	696	689	734	821	968	1298
18,000	852	1102	959	816	748	729	773	859	1014	1373
20,000	931	1239	1066	893	803	777	817	901	1067	1473

TABLE 2-3

BASIC FUEL FLOW

FUEL FLOW RATES FOR THE GIVEN CONDITIONS IN LBS/HR

PRESSURE: 2000 FT TEMPERATURE: 15 C

AIRCRAFT - UH-60A
BLACKHAWK

GROSS WEIGHTS (LBS)	FLIGHT MODE (KTS)									
	HIGE	HOGE	NOE	40	60	80	100	120	140	160
12,000	669	800	728	656	622	628	670	750	873	1137
14,000	731	901	805	708	663	660	699	774	899	1168
16,000	800	1010	890	769	711	696	733	807	937	1215
18,000	875	1133	987	840	764	739	773	845	982	1281
20,000	957	1275	1099	923	820	790	820	891	1039	1388

TABLE 2-4

BASIC FUEL FLOW

FUEL FLOW RATES FOR THE GIVEN CONDITIONS IN LBS/HR

PRESSURE: 2000 FT TEMPERATURE: 35 C

AIRCRAFT - UH-60A
BLACKHAWK

GROSS WEIGHTS (LBS)	FLIGHT MODE (KTS)									
	HIGE	HOGE	NOE	40	60	80	100	120	140	160
12,000	686	820	745	669	633	635	670	736	840	1067
14,000	750	924	824	724	677	668	699	761	866	1095
16,000	821	1036	913	789	727	705	734	792	902	1139
18,000	898	1165	1015	866	780	751	774	828	943	1203
20,000	983	1310	1132	955	840	803	823	881	1008	1321

3. DELTA FUEL FLOW FOR DRAG DATA

a. The delta fuel flow for drag is determined by five variables:

(1) Type of aircraft

(2) Altitude (air pressure)

(3) Temperature

(4) Drag surface (equivalent flat plate drag area [ft^2])

(5) Air speed

b. Tables 2-5 through 2-8 are examples of delta fuel flow for external load drag tables taken from the BLACKHAWK volume. In these tables the rows are for fixed values of drag in equivalent flat plate drag area. The fixed values for the BLACKHAWK examples shown are 25, 26 and 54 square ft. of drag. These external sling loads are of average size when compared to normal external loads of other helicopters. The columns are forward airspeeds in knots. For the BLACKHAWK helicopter these are 40, 60, 80, 100, 120, 140, and 160 kts.

c. When an external load is placed on the helicopter, the amount of fuel consumed per hour increases. The delta fuel flow for drag tables indicate how much extra fuel consumption to add to the basic fuel flow rate.

d. Using the example given earlier, a 30 minute flight at 80 kts airspeed, 2000 ft altitude, 15°C temperature, and a gross weight of 18,000 lbs in the BLACKHAWK aircraft would give (from Table 2-3) a basic fuel flow rate of 739 lbs/hr or 370 lbs per 30 minutes. If part of the load was an external sling load inducing a 36 equivalent sq ft external drag, the Delta Fuel Flow for Drag from Table 2-7 (56 lbs/hr) should be added to the basic fuel flow rate. Thus the fuel flow rate becomes 739 + 56 or 795 lbs per hour. For a half-hour flight 398 lbs of fuel is used instead of 370 lbs without an external load.

e. Interpolation can also be used on the delta fuel flow for drag tables if the desired rate is not directly listed in the table.

f. Similar to the basic fuel flow tables, there are also 24 tables for delta fuel flow for drag presented in each of the other eight volumes. The same 24 combinations of temperature and altitude are used for delta fuel flow for drag as were used for the basic fuel flow.

TABLE 2-5

CORRECTION FUEL FLOW LBS/HR FOR EXTERNAL DRAG

PRESSURE: 2000 FT   TEMPERATURE: -25 C

AIRCRAFT - UH-60A
BLACKHAWK

DRAG IN SQUARE FEET		AIR SPEED IN KTS						
		40	60	80	100	120	140	160
	25	6	19	46	94	172	305	611
	36	8	28	67	136	251	457	922
	54	12	42	101	208	390	732	1428

TABLE 2-6

CORRECTION FUEL FLOW LBS/HR FOR EXTERNAL DRAG

PRESSURE: 2000 FT TEMPERATURE: -5 C

AIRCRAFT - UH-60A
BLACKHAWK

		AIR SPEED IN KTS						
		40	60	80	100	120	140	160
DRAG IN SQUARE FEET	25	5	18	42	85	155	266	488
	36	8	25	61	124	226	396	757
	54	11	38	92	188	347	628	1229

TABLE 2-7

CORRECTION FUEL FLOW LBS/HR FOR EXTERNAL DRAG

PRESSURE: 2000 FT   TEMPERATURE: 15 C

AIRCRAFT - UH-60A
BLACKHAWK

		AIR SPEED IN KTS						
		40	60	80	100	120	140	160
DRAG IN SQUARE FEET	25	5	16	39	78	142	239	422
	36	7	24	56	114	206	352	636
	54	11	35	85	173	315	555	1063

TABLE 2-8

CORRECTION FUEL FLOW LBS/HR FOR EXTERNAL DRAG

PRESSURE: 2000 FT TEMPERATURE: 35 C

AIRCRAFT - UH-60A
BLACKHAWK

DRAG IN SQUARE FEET	AIR SPEED IN KTS 40	60	80	100	120	140	160
25	5	15	36	72	130	218	368
36	7	22	52	105	189	319	553
54	10	33	79	159	289	496	894

TABLE 2-9

GROUND IDLE FUEL FLOW

AIRCRAFT - UH-60A

BLACKHAWK

		PRESSURE ALTITUDE (FT)					
		SEA LEVEL	2000	4000	6000	8000	10000
TEMPERATURE DEGREES CENTIGRADE	-25 C	567	529	491	459	426	395
	-5 C	557	521	484	452	419	388
	15 C	549	509	477	446	414	372
	35 C	549	510	477	443	409	378

ENTRIES ARE AIRCRAFT FUEL FLOW RATES IN LBS/HR

4. GROUND IDLE FUEL FLOW DATA

a. The ground idle fuel flow rate is determined by three variables:

(1) Type of aircraft

(2) Altitude (air pressure)

(3) Temperature

b. For each aircraft there is only one ground idle fuel flow table. Each table has four rows of temperatures: -25°C, -5°C, 15°C and 35°C; and six columns of altitudes: Sea Level, 2000 ft., 4000 ft., 6000 ft., 8000 ft., and 10,000 ft. These rows and columns have the same headings for all helicopters.

c. Table 2-9 is the ground idle fuel flow table for the BLACKHAWK helicopter. An example of using the ground idle fuel flow table is presented using a BLACKHAWK helicopter idling for 20 minutes at 2000 ft altitude and 15°C. Looking across the row labeled 15° and down the column labeled 2000 they intersect at 509. Thus the BLACKHAWK uses 509 lbs/hr at these conditions; therefore, idling for 20 minutes (1/3 of an hour) it will use 170 lbs of fuel.

d. If the helicopter was only 1000 ft above sea level, the consumption rate is found by interpolating between the sea level rate of 549 lbs/hr and the 2000 ft rate of 509 lbs/hr. This rate is 529 lbs/hr. In 1/3 of an hour 176 lbs of fuel is used. In the same way, if the desired temperature is not listed, interpolate.

5. GROSS WEIGHT LIMITS DATA

a. Gross weight limits tables (Tables 2-10 through 2-15) show if the aircraft can safely take off using four sets of criteria. These criteria are defined in the following paragraphs:

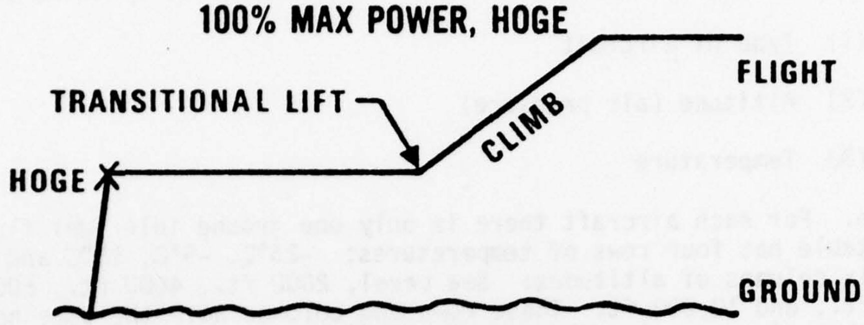
(1) Criteria #1: The helicopter uses 100% of maximum power for take off and has enough power to lift straight up and out of ground effect (see Figure 2-1). Once it is hovering out of ground effect it must begin forward flight until it acquires transitional lift to be able to climb 450 ft/min to the desired altitude. This criteria is considered to have some risk since the pilot is using all of his power and has no reserve. It has less risk than Criteria #3 but more than Criteria #2, thus it is considered to be "middle of the road" for risk.

(2) Criteria #2: The helicopter uses 95% of maximum power for take off to immediately begin to climb at a rate of 450 ft/min (Figure 2-1). This is the least risky criteria since the pilot has 5% of his power in reserve and is still able to climb at a satisfactory rate.

CRITERIA #1

(MIDDLE OF THE ROAD)

100% MAX POWER, HOGE



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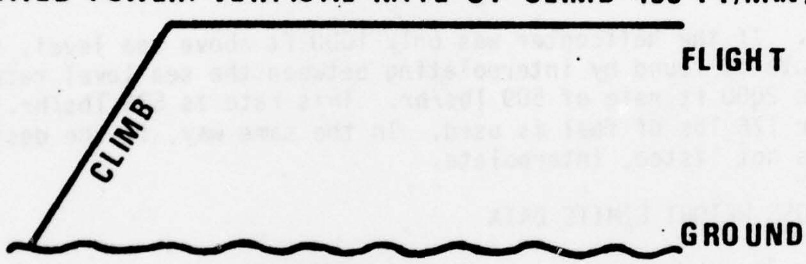
CRITERIA #2

(LEAST RISKY)

95% OF RATED POWER. VERTICAL RATE OF CLIMB 450 FT/MIN, HOGE



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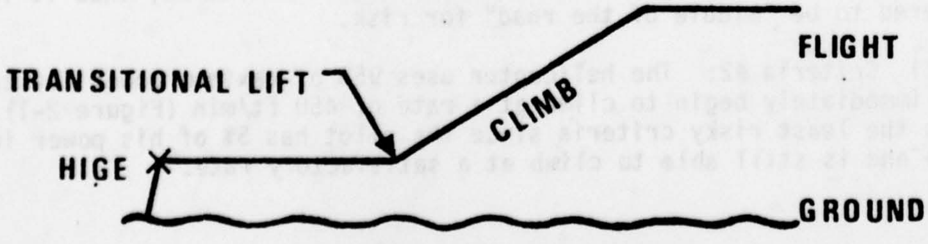
CRITERIA #3

(MOST RISKY)

100% MAX POWER, HIGE



NOTHING TO SPARE.

Figure 2-1

(3) Criteria #3: The helicopter uses 100% of maximum power and is only able to hover in ground effect (Figure 2-1). At a low altitude, the pilot must begin forward flight until he builds up enough airspeed to acquire transitional lift and begin to climb. The reasons for its high risk are readily apparent. First, there is no power in reserve. Secondly, forward flight starts at a very low altitude.

(4) Criteria #4: Structural Gross Weight Limit is the total upper limit of gross weight the helicopter can carry under any take off criteria.

b. Gross Weight Limits are determined by four variables:

(1) Type aircraft

(2) Criteria chosen

(3) Altitude (air pressure)

(4) Temperature

c. Additionally, Criteria #1, #2, and #3 differ due to engine power limits or transmission power limits of the aircraft. Thus, there are six tables for these 3 criteria:

(1) Criteria #1 (due to engine) [Table 2-10]

(2) Criteria #1 (due to transmission) [Table 2-11]

(3) Criteria #2 (due to engine) [Table 2-12]

(4) Criteria #2 (due to transimission) [Table 2-13]

(5) Criteria #3 (due to engine) [Table 2-14]

(6) Criteria #3 (due to transmission) [Table 2-15]

d. The structural gross weight limit is a single value for each helicopter and is only dependent on the type helicopter. The BLACKHAWK structural gross weight limit is 20,250 lbs and is listed at the bottom of each table. As the name implies, it is simply not safe to expect the BLACKHAWK to maneuver normally when the total weight is larger than that value.

e. In simulating a flight profile, the gross weight limits tables are used as a check to see if the aircraft is going to be too heavy to take off under the given conditions. For example, if a BLACKHAWK pilot planned a mission that called for using take off criteria #1 and the take off was to be at 6000 ft. 15°C, and at a gross weight of 18,300, three checks

TABLE 2-10

GROSS WEIGHT LIMITS
(DUE TO ENGINE)
FOR TAKEOFF CRITERIA #1
100% OF MAXIMUM POWER (HOGE)
AIRCRAFT - UH-60A
BLACKHAWK

		PRESSURE ALTITUDE (FT)					
		SEA LEVEL	2000	4000	6000	8000	10000
TEMPERATURE DEGREES CENTIGRADE	-25 C	24815	23085	21453	19922	18479	17126
	-5 C	25019	23337	21717	20175	18710	17265
	15 C	22928	21357	19880	18444	17061	15741
	35 C	20393	18979	17633	16294	14990	13754

ENTRIES ARE AIRCRAFT GROSS WEIGHTS IN LBS

STRUCTURAL GROSS WEIGHT LIMIT: 20,250 LBS

TABLE 2-11

GROSS WEIGHT LIMITS
(DUE TO TRANSMISSION)
FOR TAKEOFF CRITERIA #1
100% OF MAXIMUM POWER (HOGE)
AIRCRAFT - UH-60A
BLACKHAWK

		PRESSURE ALTITUDE (FT)					
		SEA LEVEL	2000	4000	6000	8000	10000
TEMPERATURE DEGREES CENTIGRADE	-25 C	22327	21882	21440	20997	20546	20094
	-5 C	21846	21413	20978	20536	20092	19646
	15 C	21417	20988	20553	20116	19677	19236
	35 C	21022	20593	20161	19729	19293	18857

ENTRIES ARE AIRCRAFT GROSS WEIGHTS IN LBS

STRUCTURAL GROSS WEIGHT LIMIT: 20,250 LBS

TABLE 2-12

GROSS WEIGHT LIMITS

(DUE TO ENGINE)

FOR TAKEOFF CRITERIA #2

95% OF RATED POWER. VERTICAL RATE OF CLIMB 450 FT/MIN. OGE

AIRCRAFT - UH-60A

BLACKHAWK

		PRESSURE ALTITUDE (FT)					
		SEA LEVEL	2000	4000	6000	8000	10000
TEMPERATURE DEGREES CENTIGRADE	-25 C	23354	21726	20190	18749	17391	16118
	-5 C	23573	21990	20464	19012	17631	16269
	15 C	21596	20117	18727	17374	16070	14827
	35 C	19194	17862	16596	15336	14107	12942

ENTRIES ARE AIRCRAFT GROSS WEIGHTS IN LBS

STRUCTURAL GROSS WEIGHT LIMIT: 20,250 LBS

TABLE 2-13

GROSS WEIGHT LIMITS

(DUE TO TRANSMISSION)

FOR TAKEOFF CRITERIA #2

TRANSMISSION POWER LIMIT. VERTICAL RATE OF CLIMB 450 FT/MIN. OGE

AIRCRAFT - UH-60A

BLACKHAWK

		PRESSURE ALTITUDE (FT)					
		SEA LEVEL	2000	4000	6000	8000	10000
TEMPERATURE DEGREES CENTIGRADE	-25 C	21788	21370	20948	20528	20101	19669
	-5 C	21335	20921	20509	20090	19666	19241
	15 C	20925	20519	20106	19689	19271	18849
	35 C	20550	20144	19732	19320	18904	18486

ENTRIES ARE AIRCRAFT GROSS WEIGHTS IN LBS

STRUCTURAL GROSS WEIGHT LIMIT: 20,250 LBS

TABLE 2-14

GROSS WEIGHT LIMITS
(DUE TO ENGINE)
FOR TAKEOFF CRITERIA #3
100% OF MAXIMUM POWER (HIGE)
AIRCRAFT - UH-60A
BLACKHAWK

		PRESSURE ALTITUDE (FT)					
		SEA LEVEL	2000	4000	6000	8000	10000
TEMPERATURE DEGREES CENTIGRADE	-25 C	32867	30575	28413	26385	24475	22683
	-5 C	33143	30916	28770	26728	24786	22873
	15 C	30374	28292	26336	24434	22601	20854
	35 C	27018	25144	23361	21588	19860	18222

ENTRIES ARE AIRCRAFT GROSS WEIGHTS IN LBS

STRUCTURAL GROSS WEIGHT LIMIT: 20,250 LBS

TABLE 2-15

GROSS WEIGHT LIMITS
(DUE TO TRANSMISSION)
FOR TAKEOFF CRITERIA #3
100% OF MAXIMUM POWER (HIGE)
AIRCRAFT - UH-60A
BLACKHAWK

		PRESSURE ALTITUDE (FT)					
		SEA LEVEL	2000	4000	6000	8000	10000
TEMPERATURE DEGREES CENTIGRADE	-25 C	29552	28978	28397	27810	27218	26623
	-5 C	28941	28368	27789	27207	26620	26029
	15 C	28375	27805	27230	26651	26069	25484
	35 C	27849	27282	26711	26137	25560	24981

ENTRIES ARE AIRCRAFT GROSS WEIGHTS IN LBS

STRUCTURAL GROSS WEIGHT LIMIT: 20,250 LBS

would be required: First, does this gross weight exceed the structural gross weight limit? Second, does it exceed Criteria #1 (due to engine)? Third, does it exceed Criteria #1 (due to transmission)? In the example given, the answer to all three questions is: "No." So the take off would not exceed the limits of the aircraft.

f. If the assigned gross weight had been 19,000 lbs, it would have exceeded the value given for 6,000 ft. and 15°C at Criteria #1 (due to engine). The mission could not be flown as planned. The plan could be changed, for example; take off at 4000 ft (which might not be practical), or use take off Criteria #3 (which is more risky but has higher limits).

g. If the assigned gross weight had been 20,300 lbs, it would have exceeded the structural limits. Here the only choice would be to lighten the load or get another type helicopter.

6. VELOCITY LIMITS DATA

a. There are various types of data given in these tables (Tables 2-16 through 2-19), but like the gross weight limits tables, they are primarily restraints on what can be expected of a helicopter in simulating a mission profile. Information listed in the title and headings for the rows and columns consits of:

(1) Type of aircraft

(2) Air pressure (altitude)

(3) Temperature

(4) Gross weight

(5) Condition or limit

b. Items (1) through (4) are self-explanatory. There are five types of information that can be listed under (5):

(1) Long range

(2) Maximum continuous power

(3) Maximum power (due to engine limits)

(4) Transmission limits

(5) V_{ne} (velocity never exceed)

c. The two columns headed Long Range give the optimum speed and fuel flow for each set of variables. Thus, the BLACKHAWK helicopter operating at 2000 ft, temperature 15°C, and having a gross weight of 18,000 lbs will fly the greatest distance at 138 kts and will use 964 lbs/hr of fuel (Table 2-18).

d. Maximum continuous power gives the top speed at which a helicopter can fly for long periods and the associated fuel flow rate. An example from Table 2-19 would be a BLACKHAWK helicopter at 2000' and 35°C weighing 20,000 lbs. It could fly 141 kts with a fuel usage of 1014 lbs/hr.

e. Maximum Power (Engine) and Transmission Limits show the maximum speeds the aircraft can structurally attain for short periods of time (less than 30 minutes). Thus, the BLACKHAWK helicopter at 2000' and -25°C weighing 16,000 lbs has an engine that is capable of producing enough power to fly 160 kts but the transmission limits the aircraft to 156 kts (Table 2-16).

f. There is also a possibility of some helicopters reaching a velocity that should never be exceeded which is determined by helicopter structural considerations. For some aircraft the V_{ne} has not been established. In those volumes V_{ne} will not be included. Where the V_{ne} is included it is used like the Maximum Power columns to give an air speed that should not be exceeded.

g. For each aircraft, there are 24 Velocity Limits Tables depending on air pressure and temperature combinations.

TABLE 2-16

VELOCITY LIMITS TABLE

(INCLUDING FUEL FLOW RATES)

PRESSURE: 2000 FT TEMPERATURE: -25 C

AIRCRAFT - UH-60A BLACKHAWK

GROSS WEIGHTS (LBS)	LONG RANGE		MAX CONTINUOUS POWER		MAX POWER (ENGINE)		TRANSMISSION LIMITS	
	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)
12,000	131	873	166	1514	164	1466	160	1343
14,000	132	906	164	1514	162	1466	158	1343
16,000	132	941	161	1514	160	1466	156	1343
18,000	131	976	159	1514	157	1466	153	1343
20,000	128	1002	155	1514	154	1466	149	1343

TABLE 2-17

VELOCITY LIMITS TABLE

(INCLUDING FUEL FLOW RATES)

PRESSURE: 2000 FT TEMPERATURE: -5 C

AIRCRAFT - UH-60A BLACKHAWK

GROSS WEIGHTS (LBS)	LONG RANGE		MAX CONTINUOUS POWER		MAX POWER (ENGINE)		TRANSMISSION LIMITS	
	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)
12,000	136	871	167	1360	175	1533	167	1347
14,000	136	895	166	1360	174	1533	165	1347
16,000	135	928	162	1360	170	1533	162	1347
18,000	135	968	159	1360	167	1533	159	1347
20,000	134	1009	156	1360	162	1533	155	1347

TABLE 2-18

VELOCITY LIMITS TABLE

(INCLUDING FUEL FLOW RATES)

PRESSURE: 2000 FT TEMPERATURE: 15 C

AIRCRAFT - UH-60A BLACKHAWK

GROSS WEIGHTS (LBS)	LONG RANGE		MAX CONTINUOUS POWER		MAX POWER (ENGINE)		TRANSMISSION LIMITS	
	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)
12,000	140	872	162	1174	175	1403	172	1351
14,000	140	900	160	1174	173	1403	171	1351
16,000	140	935	158	1174	170	1403	168	1351
18,000	138	964	154	1174	166	1403	163	1351
20,000	137	1007	150	1174	161	1403	159	1351

TABLE 2-19

VELOCITY LIMITS TABLE

(INCLUDING FUEL FLOW RATES)

PRESSURE: 2000 FT   TEMPERATURE: 35 C

AIRCRAFT - UH-60A BLACKHAWK

GROSS WEIGHTS (LBS)	LONG RANGE		MAX CONTINUOUS POWER		MAX POWER (ENGINE)		TRANSMISSION LIMITS	
	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)
12,000	143	866	156	1014	173	1253	180	1357
14,000	143	894	154	1014	171	1253	178	1357
16,000	143	928	151	1014	168	1253	175	1357
18,000	142	965	147	1014	163	1253	169	1357
20,000	141	1019	141	1014	157	1253	162	1357

CHAPTER 3

METHODOLOGY DEVELOPMENT

GRAPHICAL ANALYSIS

1. GENERAL

After AVRADCOM supplied the data for the various helicopters, it was analyzed for errors and the interpolation procedure was checked by calculating points between the known data points. The first analysis was to graph the data across various fixed, dependent and independent variables. This chapter describes this analysis.

2. BASIC FUEL FLOW GRAPHS (Figures 3-1 through 3-10)

a. The basic fuel flow data was given a rigorous analysis since it was the most important and the most sensitive. The first four figures (Figures 3-1 through 3-4) are plots of the data as it was received. These four graphs show the plots of the basic fuel flow tables that were given in Tables 2-1 through 2-4. Of the five variables that determine basic fuel flow, three are held fixed (aircraft, altitude and temperature), and one is independent (flight mode). The rate of fuel flow is plotted for each set of gross weights. The y-axis is the rate of fuel flow in pounds per hour. The x-axis is the flight mode of the aircraft in knots. To avoid different scales for HIGE, HOGE, NOE and forward flight the following arbitrary "speeds" were assigned for presentation purposes only:

(1) HIGE - 0 to 10 kts

(2) HOGE - 10 to 20 kts

(3) NOE - 20 to 40 kts

b. Each figure presents the fuel flow rates for five different gross weights at a given altitude and temperature. For example, the plot labeled "A: is the plot for 12,000 lbs. These labels are further explained by the heading on the figure. The figure heading also identifies the aircraft, the temperature and the pressure (altitude) for each figure.

c. This set of figures shows the accuracy of the data in several ways. The different gross weight curves are all approximately the same type of curve. There is a fairly even increment between curves. The curves are in general smooth, all of which reflect the consistency of the data. This also assures that values not stated in the tables can be found accurately by interpolation.

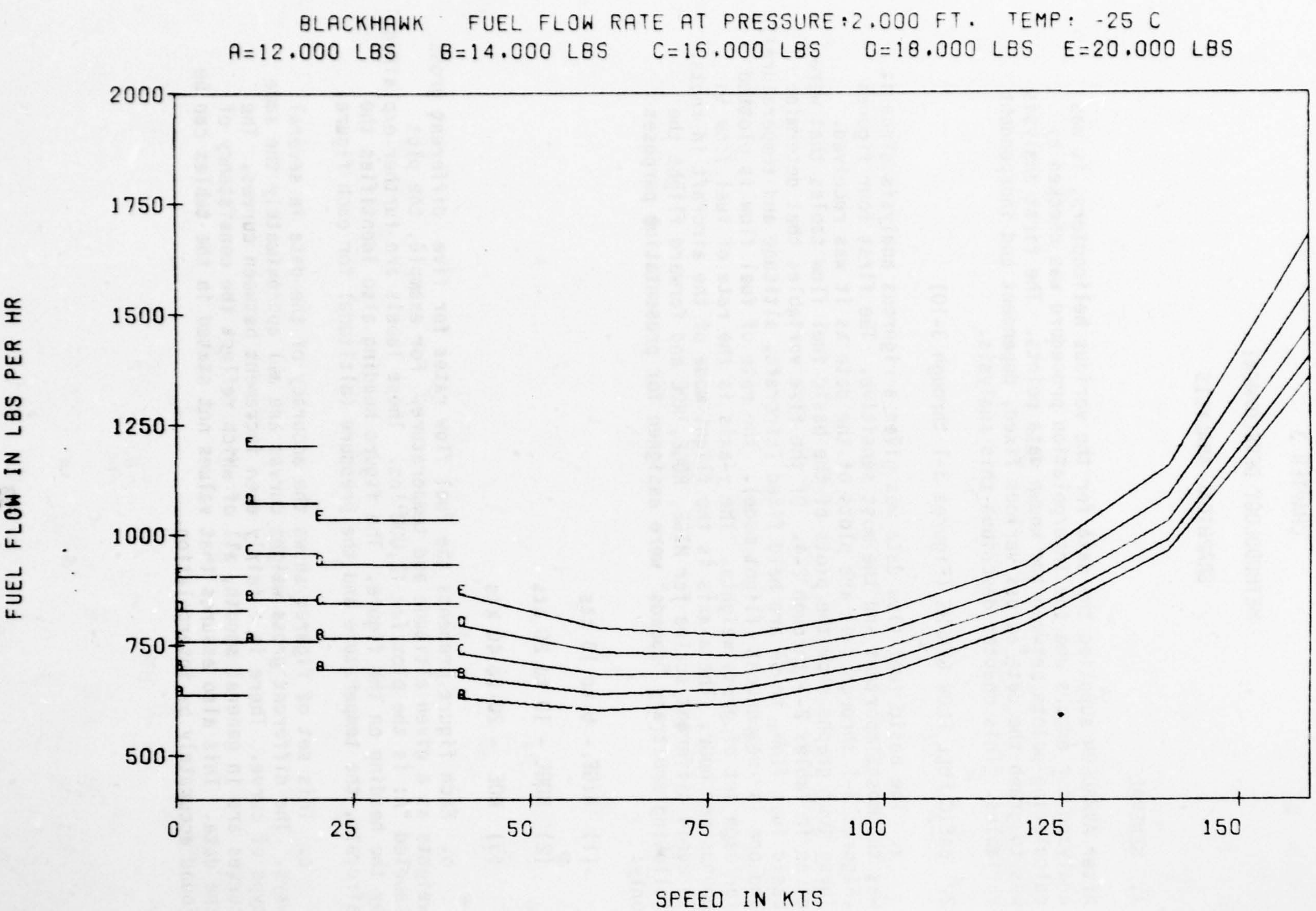

BLACKHAWK FUEL FLOW RATE AT PRESSURE:2.000 FT. TEMP: -25 C
A=12.000 LBS B=14.000 LBS C=16.000 LBS D=18.000 LBS E=20.000 LBS
FUEL FLOW IN LBS PER HR
2000
1750
1500
1250
1000
750
500
0
25
50
75
100
125
150
SPEED IN KTS

Figure 3-1

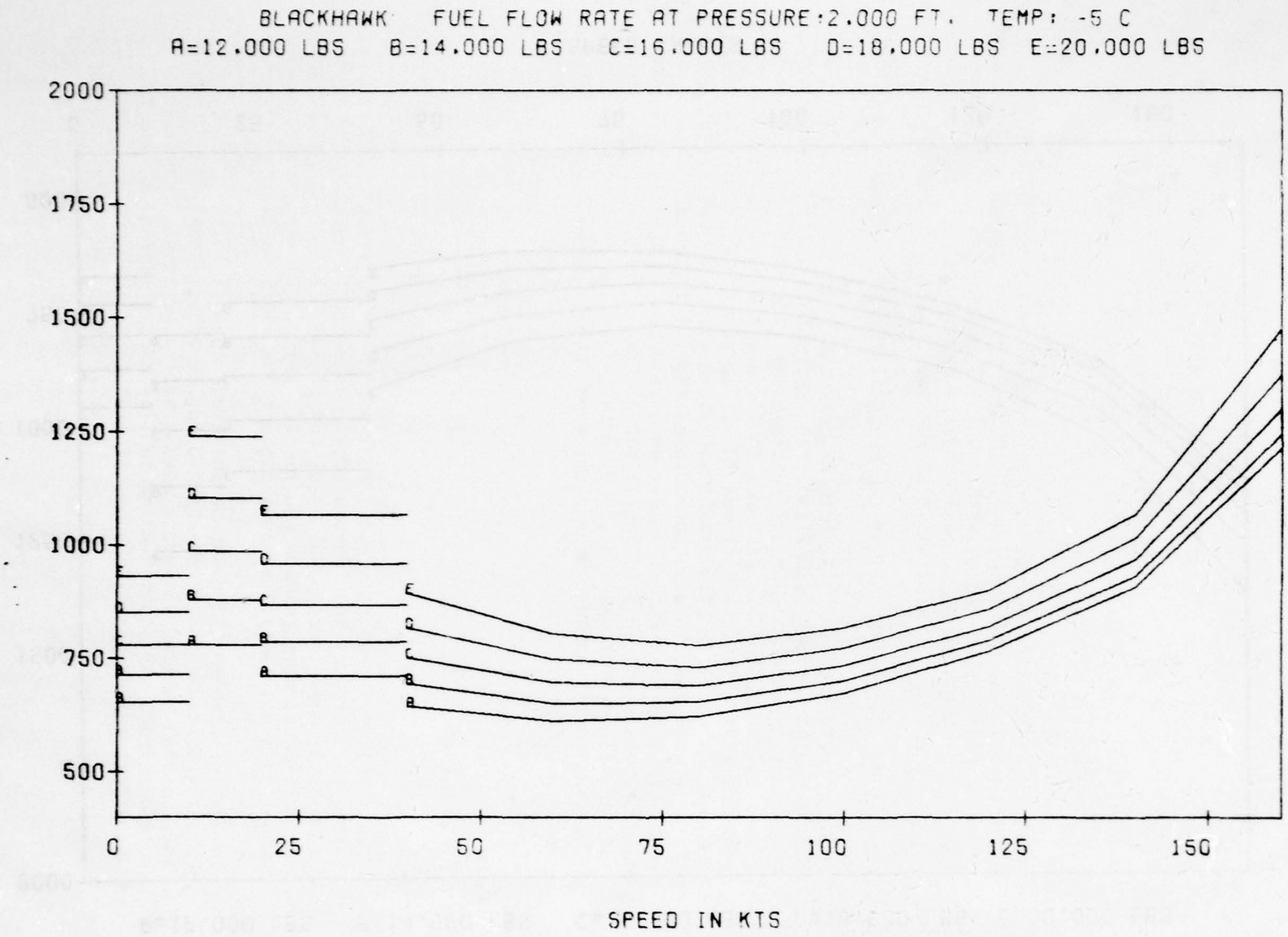

BLACKHAWK FUEL FLOW RATE AT PRESSURE:2.000 FT. TEMP: -5 C
A=12.000 LBS B=14.000 LBS C=16.000 LBS D=18.000 LBS E=20.000 LBS
FUEL FLOW IN LBS PER HR
2000
1750
1500
1250
1000
750
500
0
25
50
75
100
125
150
SPEED IN KTS

Figure 3-2

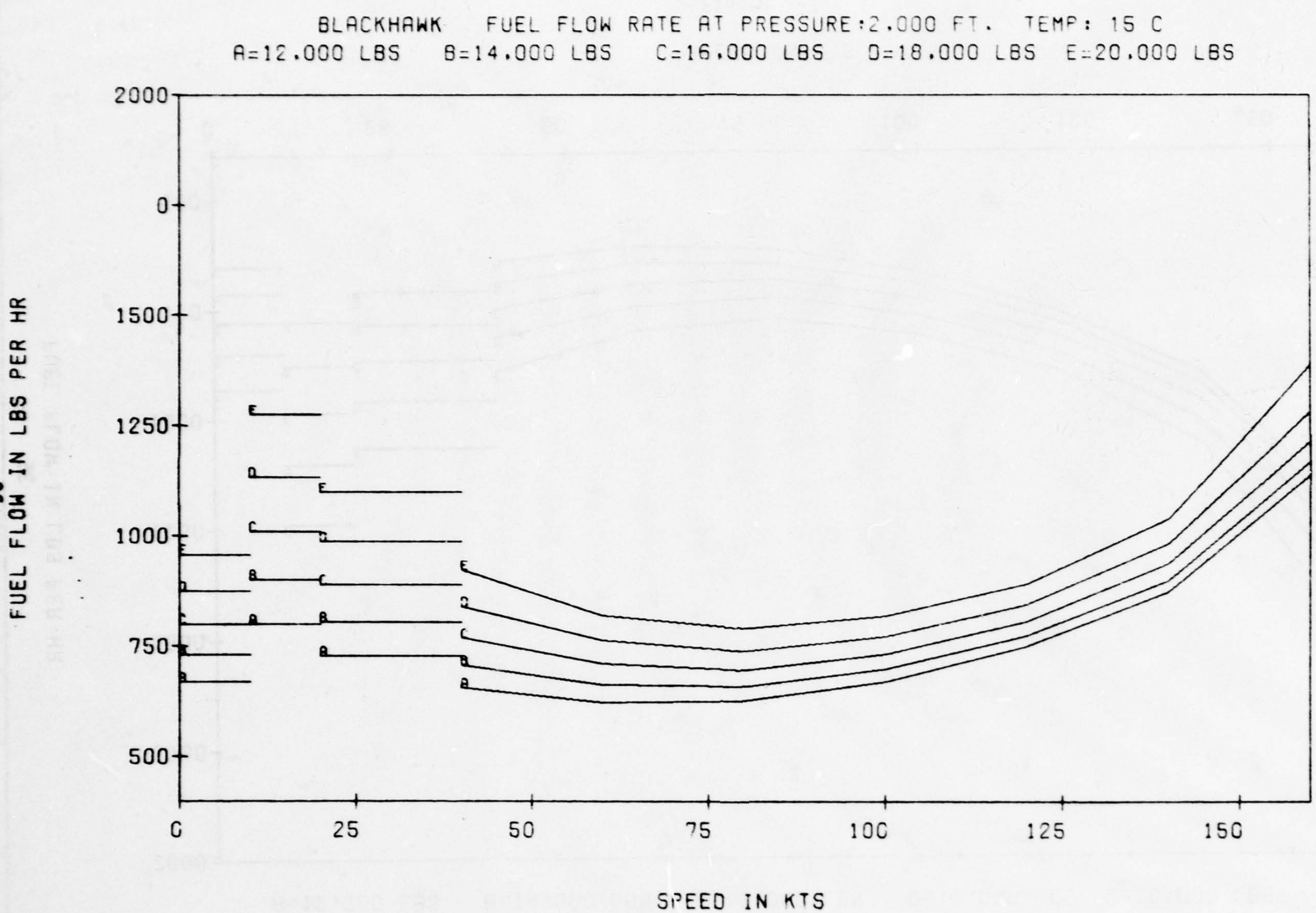

BLACKHAWK FUEL FLOW RATE AT PRESSURE:2.000 FT. TEMP: 15 C
A=12.000 LBS B=14.000 LBS C=16.000 LBS D=18.000 LBS E=20.000 LBS
FUEL FLOW IN LBS PER HR
2000
0
1500
1250
1000
750
500
0
25
50
75
100
125
150
SPEED IN KTS

Figure 3-3

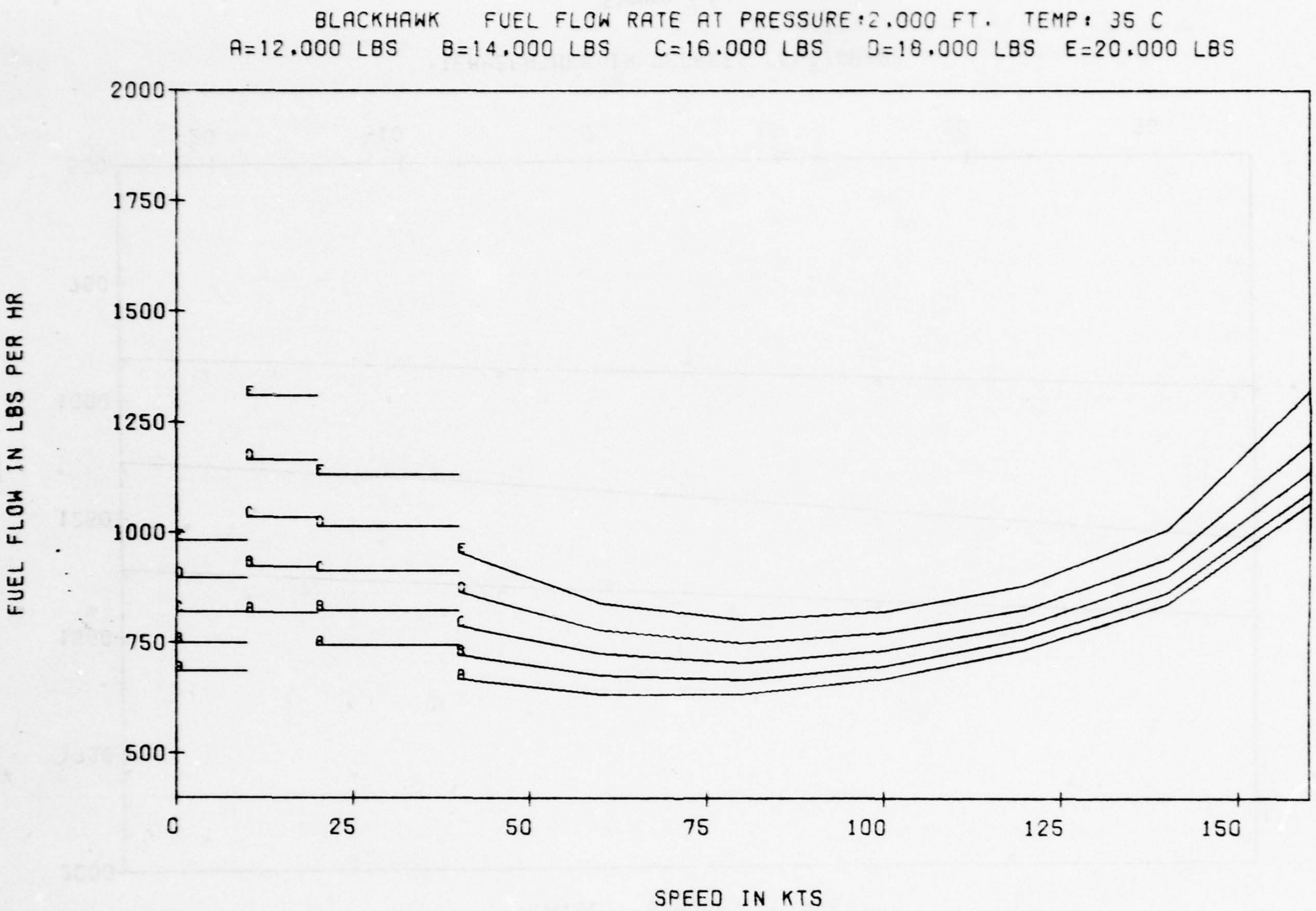
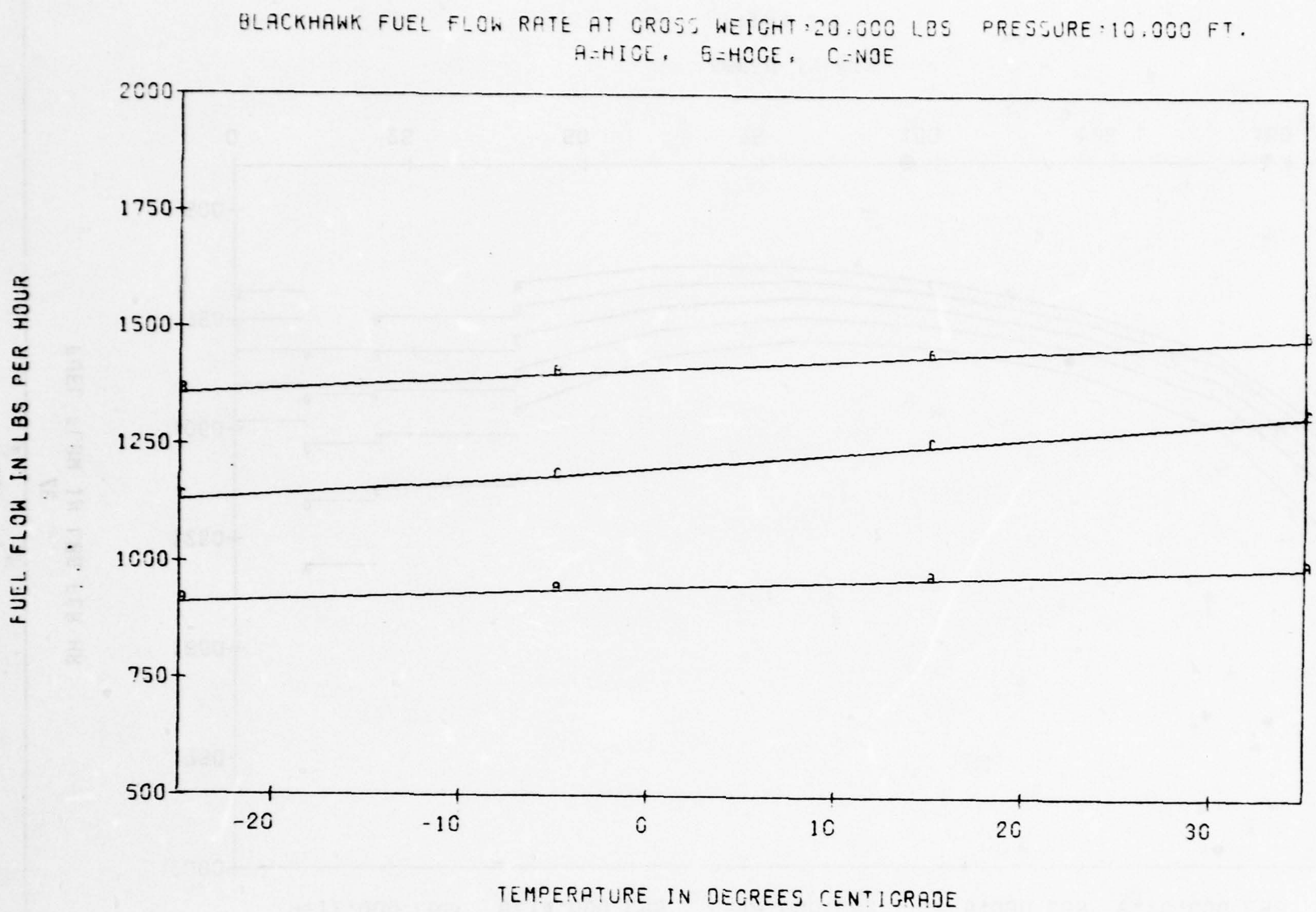

BLACKHAWK FUEL FLOW RATE AT PRESSURE:2.000 FT. TEMP: 35 C
A=12.000 LBS B=14.000 LBS C=16.000 LBS D=18.000 LBS E=20.000 LBS
FUEL FLOW IN LBS PER HR
2000
1750
1500
1250
1000
750
500
0
25
50
75
100
125
150
SPEED IN KTS

Figure 3-4



BLACKHAWK FUEL FLOW RATE AT GROSS WEIGHT:20,000 LBS PRESSURE:10,000 FT.
A=HICE, B=HOGE, C=NOE
FUEL FLOW IN LBS PER HOUR
2000
1750
1500
1250
1000
750
500
-20
-10
0
10
20
30
TEMPERATURE IN DEGREES CENTIGRADE

Figure 3-5

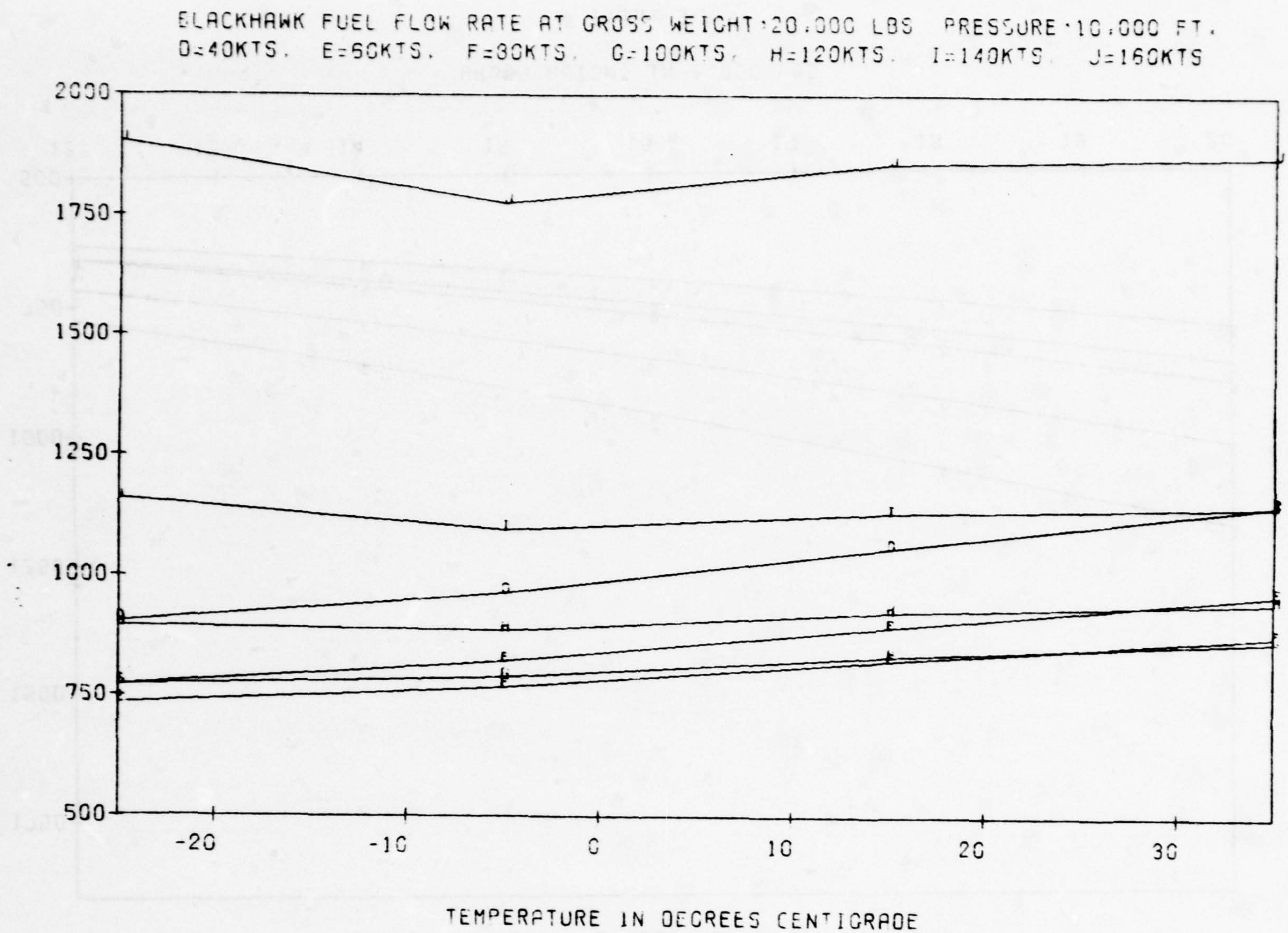

BLACKHAWK FUEL FLOW RATE AT GROSS WEIGHT 20,000 LBS PRESSURE 10,000 FT.
D=40KTS. E=60KTS. F=80KTS. G=100KTS. H=120KTS. I=140KTS. J=160KTS
2000
1750
1500
1250
1000
750
500
-20
-10
0
10
20
30
TEMPERATURE IN DEGREES CENTIGRADE
FUEL FLOW IN LBS PER HOUR

Figure 3-6

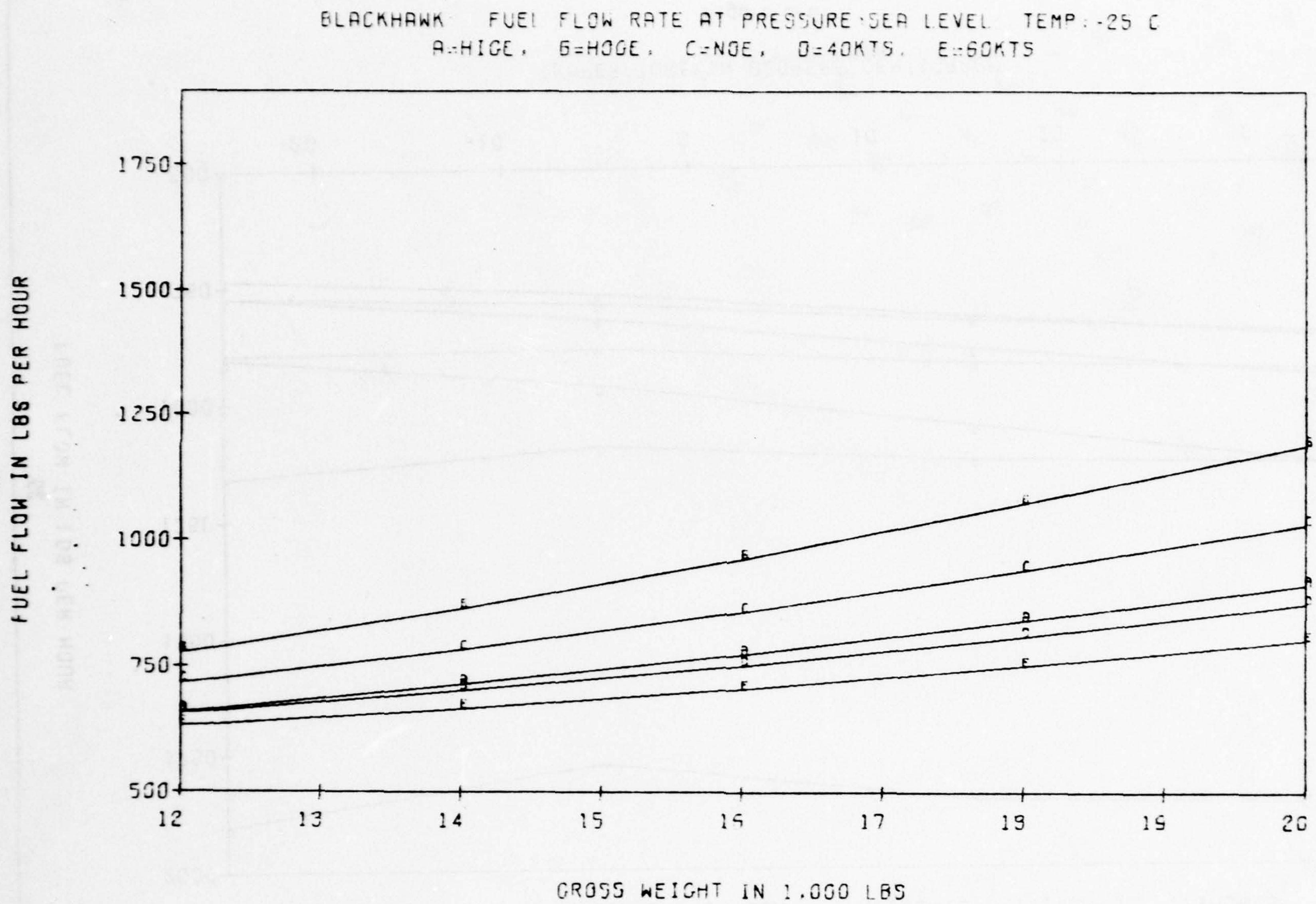

BLACKHAWK FUEL FLOW RATE AT PRESSURE:SEA LEVEL TEMP:-25 C
A=HIGE, B=HOGE, C=NOE, D=40KTS, E=60KTS
FUEL FLOW IN LBS PER HOUR
1750
1500
1250
1000
750
500
12
13
14
15
16
17
18
19
20
GROSS WEIGHT IN 1,000 LBS

Figure 3-7

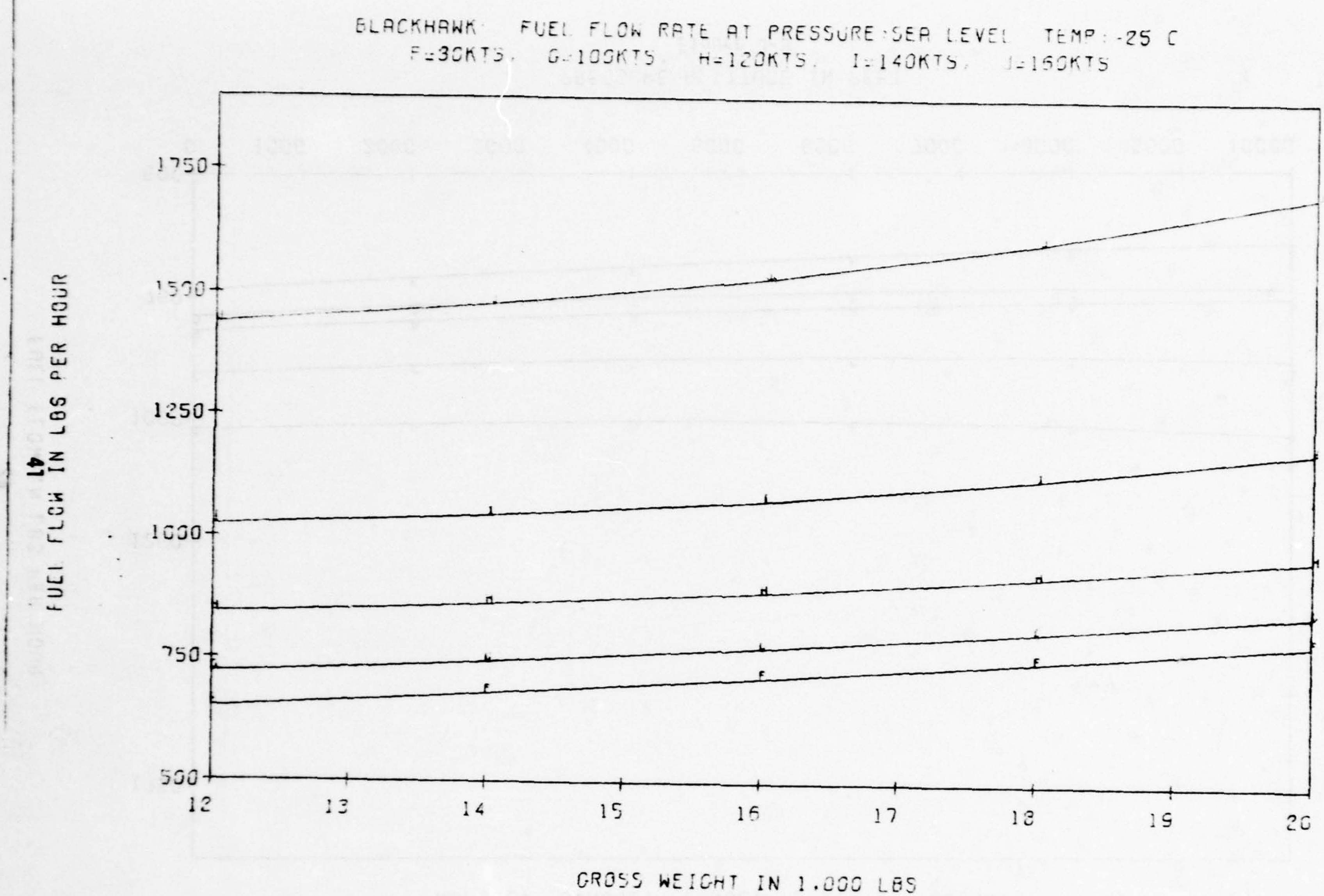

BLACKHAWK FUEL FLOW RATE AT PRESSURE:SEA LEVEL TEMP:-25 C
F=30KTS, G=100KTS, H=120KTS, I=140KTS, J=160KTS
1750
1500
1250
1000
750
500
12
13
14
15
16
17
18
19
20
FUEL FLOW IN LBS PER HOUR
GROSS WEIGHT IN 1,000 LBS

Figure 3-8

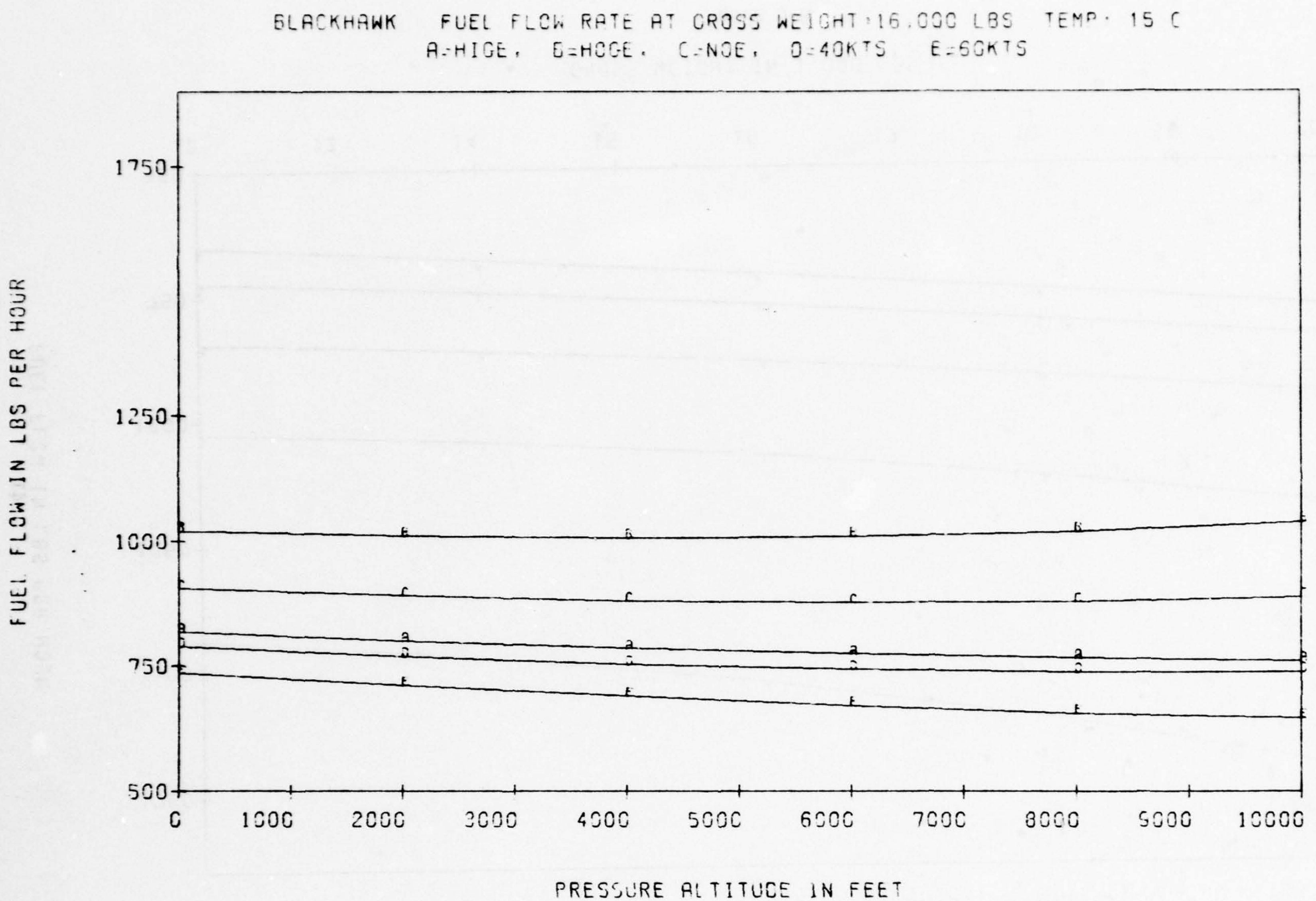

BLACKHAWK FUEL FLOW RATE AT GROSS WEIGHT 16,000 LBS TEMP 15 C
A=HIGE, B=HOGE, C=NOE, D=40KTS E=60KTS
FUEL FLOW IN LBS PER HOUR
1750
1250
1000
750
500
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PRESSURE ALTITUDE IN FEET

Figure 3-9

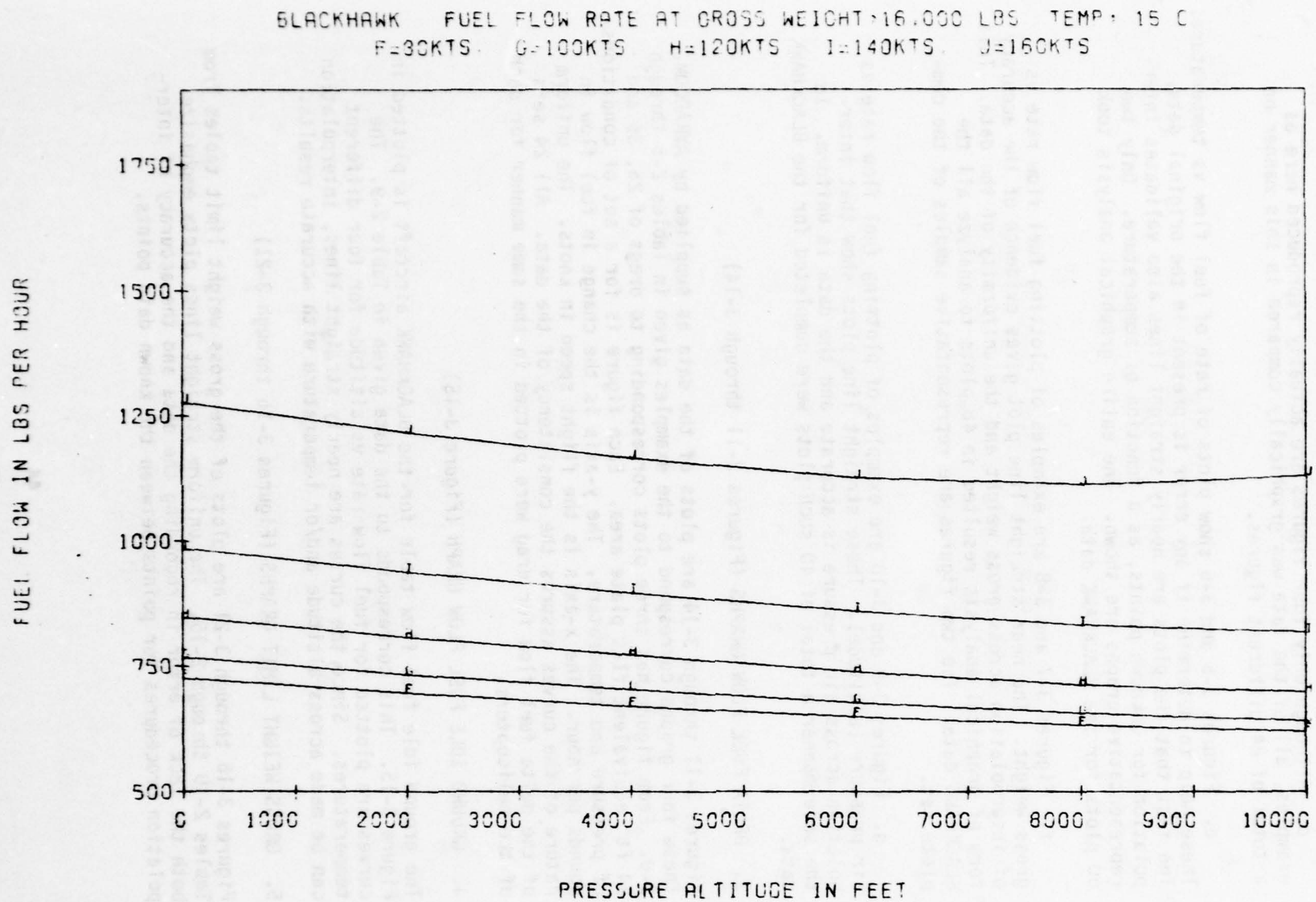

BLACKHAWK FUEL FLOW RATE AT GROSS WEIGHT 16,000 LBS TEMP: 15 C
F=30KTS G=100KTS H=120KTS I=140KTS J=160KTS
FUEL FLOW IN LBS PER HOUR
1750
1500
1250
1000
750
500
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PRESSURE ALTITUDE IN FEET

Figure 3-10

d. Although only four figures are actually reproduced here as examples, all of the data was graphically compared in this manner on a total of 24 different figures.

e. Figures 3-5 and 3-6 show plots of rate of fuel flow vs temperature. These help to determine if any error is present in the original data. The fact that the plots are nearly straight lines also validates interpolation for unknown points, as a function of temperature. Only two representative graphs are shown. The entire graphical analysis took 60 plots for the BLACKHAWK data.

f. Figures 3-7 and 3-8 are examples of plotting fuel flow rate vs gross weight. The near straight line plot gives evidence of the accuracy of interpolation across gross weight and the uniformity of the data. This form of graphical analysis resulted in 48 plots to analyze all the BLACKHAWK data. The two figures are representative samples of the complete set.

g. Figures 3-9 and 3-10 are examples of plotting fuel flow rate vs air pressure (altitude). These straight line plots show that interpolation across air pressure is accurate and the data is uniform. In the same manner a total of 40 such plots were completed for the BLACKHAWK data.

3. DELTA FUEL FLOW GRAPHS (Figures 3-11 through 3-14)

Figures 3-11 through 3-14 are plots of the data as supplied by AVRADCOM. These four graphs correspond to the examples given in Tables 2-5 through 2-8. Each figure has three plots corresponding to drags of 25, 36 and 54 ft^2 equivalent flat plate area. Each figure is for a set of conditions of pressure and temperature. The y-axis is the change in fuel flow in pounds per hour. The x-axis is the flight speed in knots. The uniform nature of the curves assures the consistency of the data. All 24 sets of the delta fuel flow for drag were plotted in the same manner for each of the helicopters.

4. GROUND IDLE FUEL FLOW GRAPH (Figure 3-15)

The ground idle fuel flow table for the BLACKHAWK aircraft is plotted in Figure 3-15. This corresponds to the data given in Table 2-9. The curves are plotted for fuel flow rate vs altitude for four different temperatures. Since the curves are nearly straight lines, interpolation can be made across altitude and/or temperature with accurate results.

5. GROSS WEIGHT LIMIT GRAPHS (Figures 3-16 through 3-21)

Figures 3-16 through 3-21 are plots of the gross weight limit tables from Tables 2-10 through 2-15. The uniform straight lines plots emphasize both the lack of error in recording the data and the accuracy of interpolation procedures for points between the known data points.

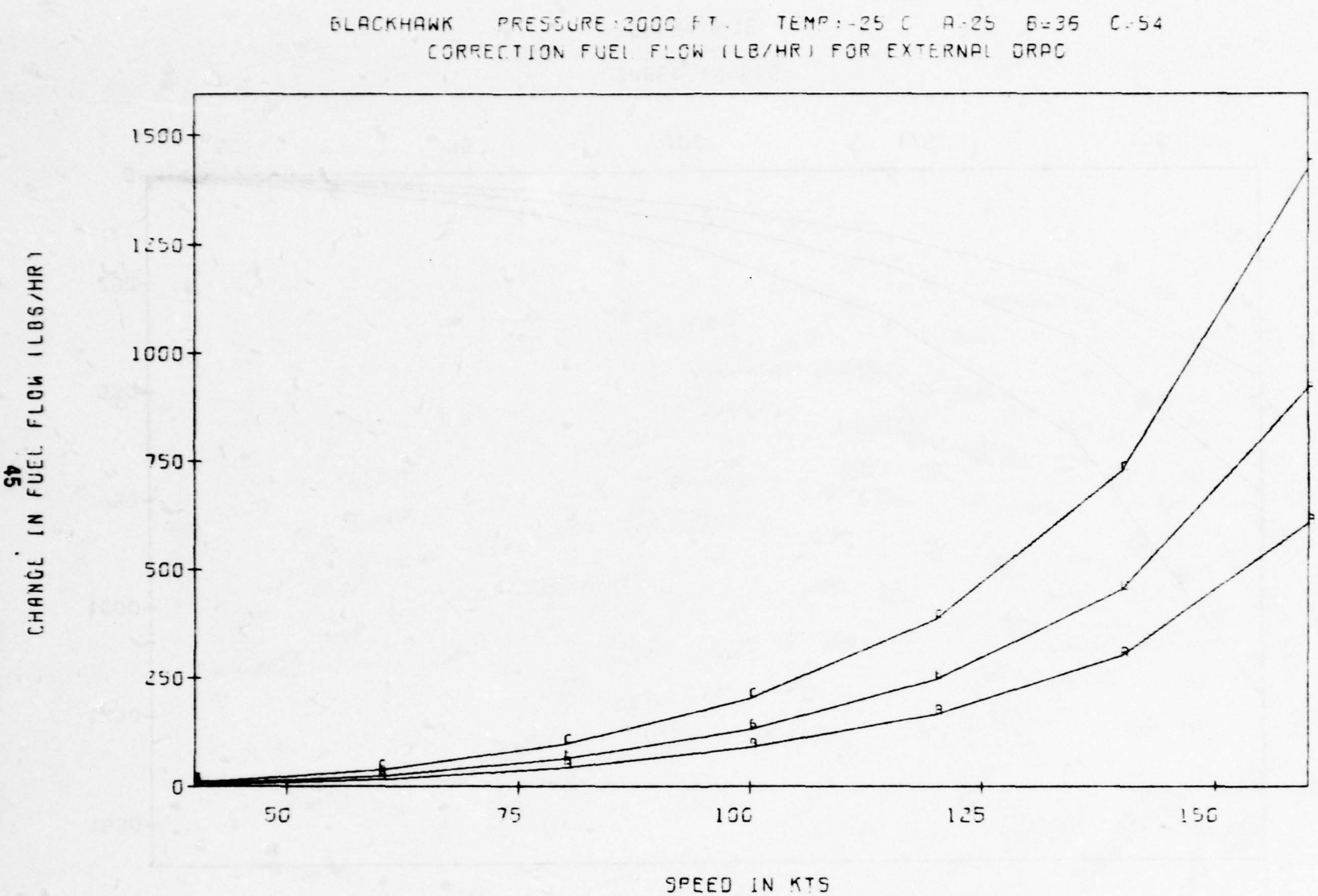

BLACKHAWK PRESSURE:2000 FT. TEMP:-25 C A-25 B=36 C-54
CORRECTION FUEL FLOW (LB/HR) FOR EXTERNAL DRAG
1500
1250
1000
750
500
250
0
50
75
100
125
150
CHANGE IN FUEL FLOW (LBS/HR)
SPEED IN KTS

Figure 3-11

BLACKHAWK PRESSURE:2000 FT TEMP:-5 C A=25 B=36 C=54
CORRECTION FUEL FLOW (LB/HR) FOR EXTERNAL DRAG

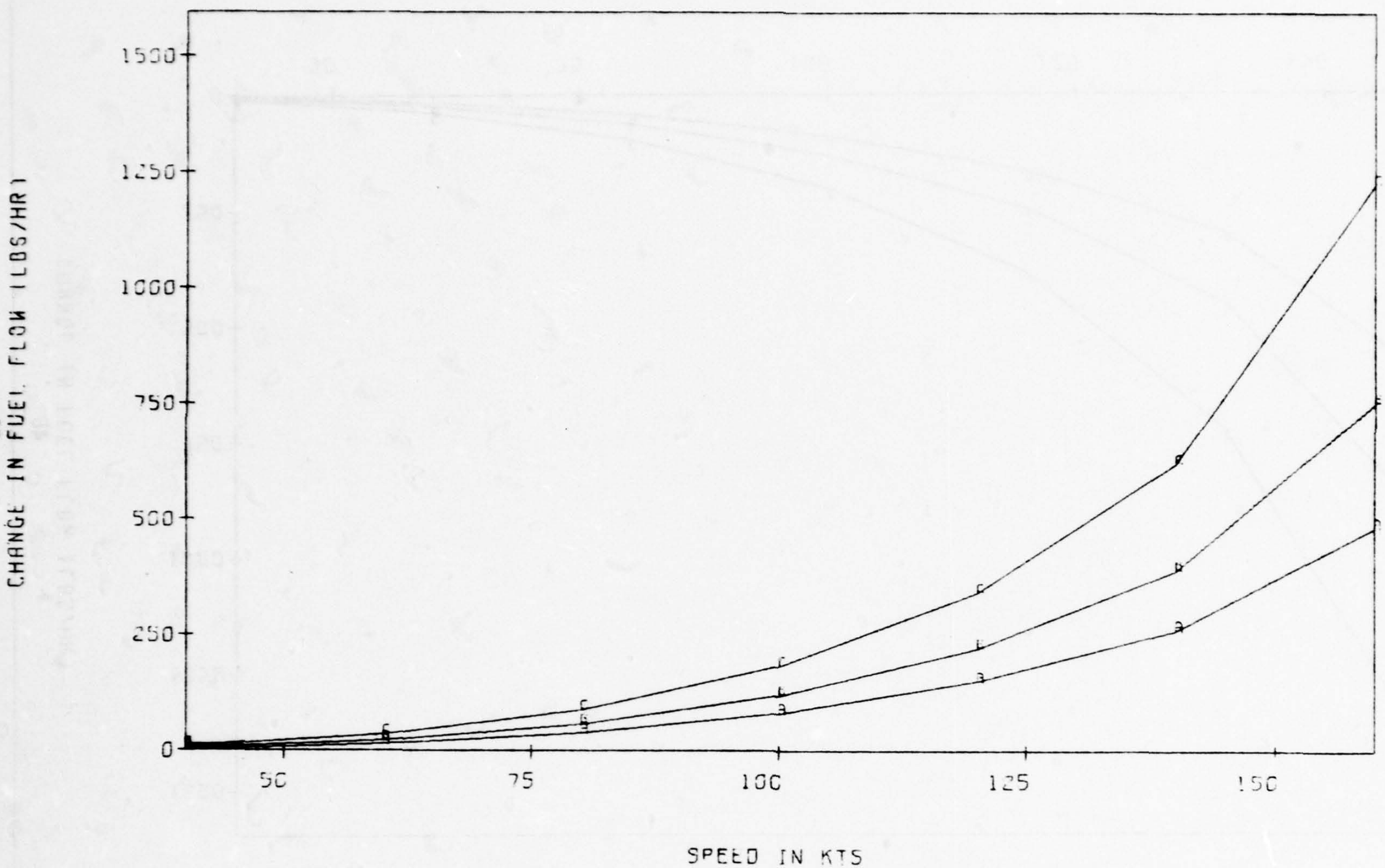


Figure 3-12

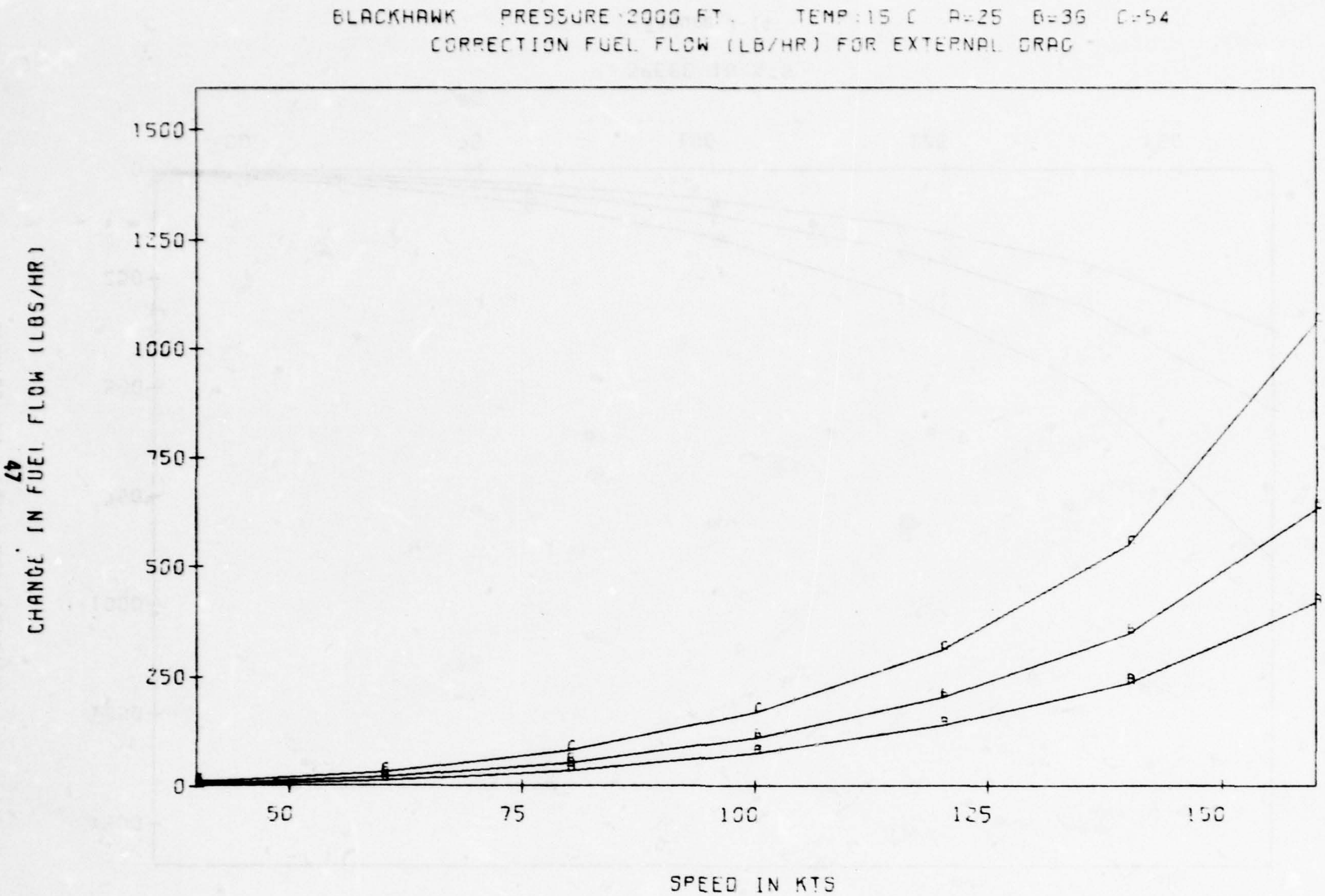

BLACKHAWK PRESSURE 2000 FT. TEMP:15 C A=25 B=36 C=54
CORRECTION FUEL FLOW (LB/HR) FOR EXTERNAL DRAG
CHANGE IN FUEL FLOW (LBS/HR)
1500
1250
1000
750
500
250
0
50
75
100
125
150
SPEED IN KTS

Figure 3-13

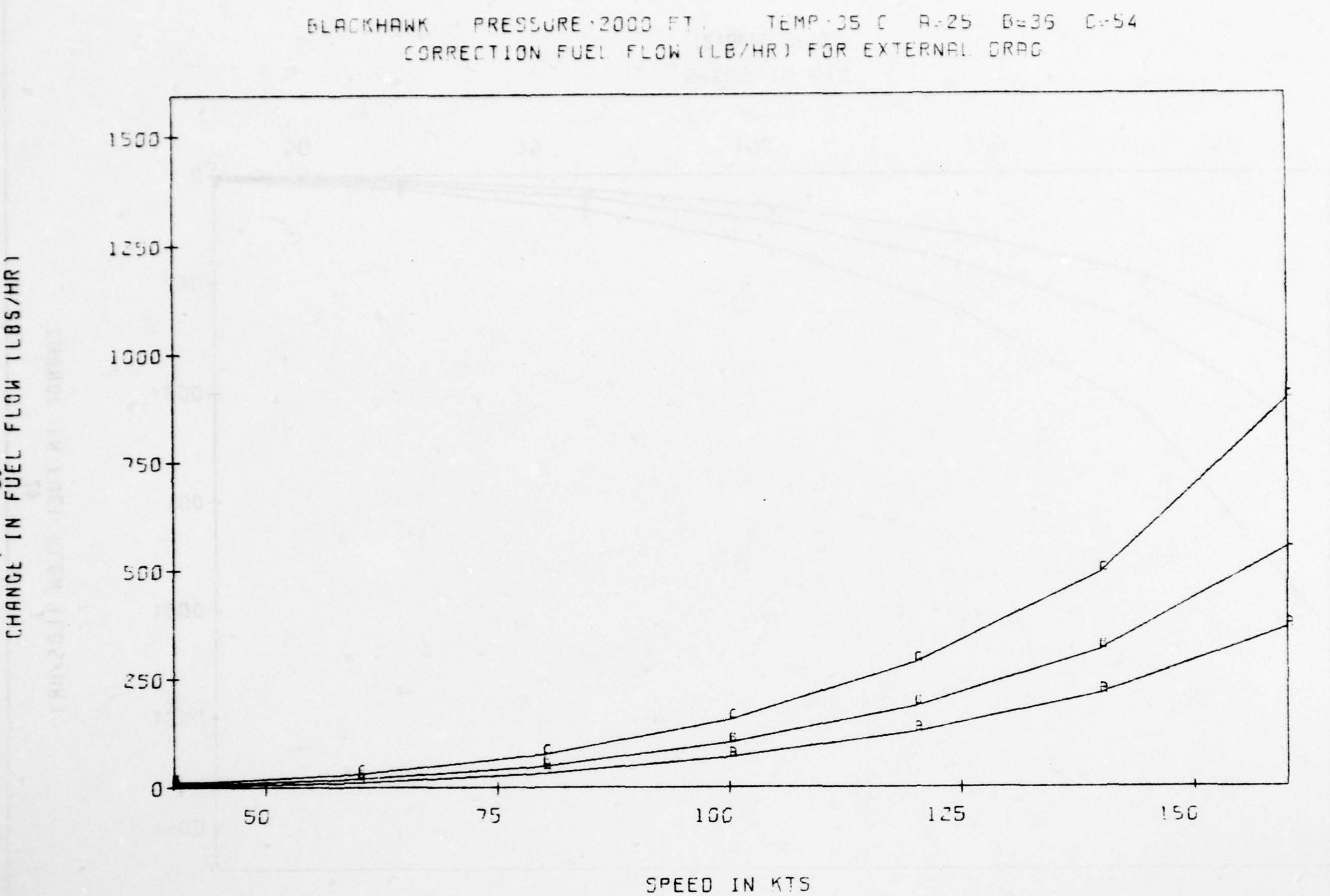

BLACKHAWK PRESSURE 2000 FT TEMP 35 C A=25 B=36 C=54
CORRECTION FUEL FLOW (LB/HR) FOR EXTERNAL DRAG
CHANGE IN FUEL FLOW (LBS/HR)
1500
1250
1000
750
500
250
0
50
75
100
125
150
SPEED IN KTS

Figure 3-14

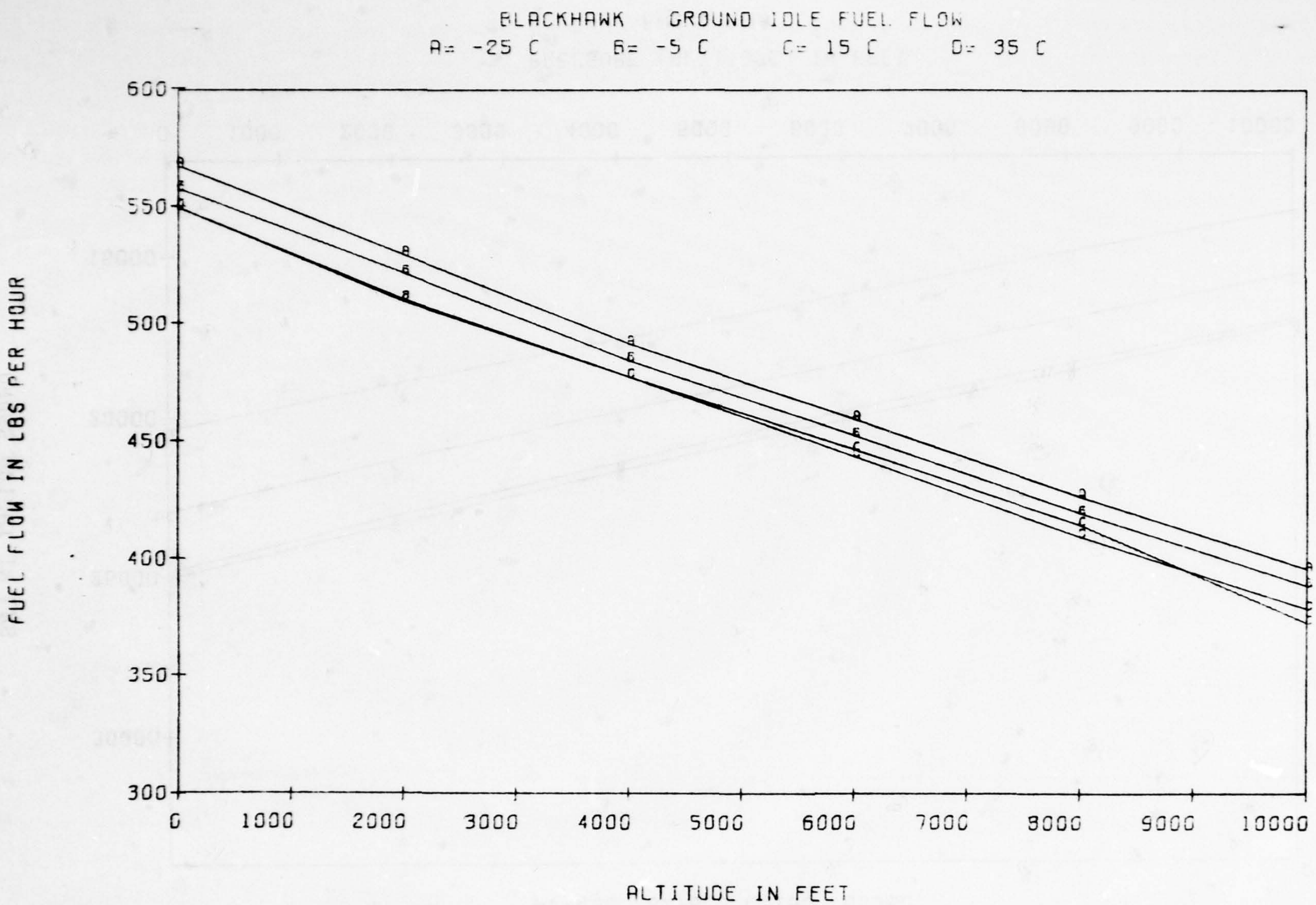
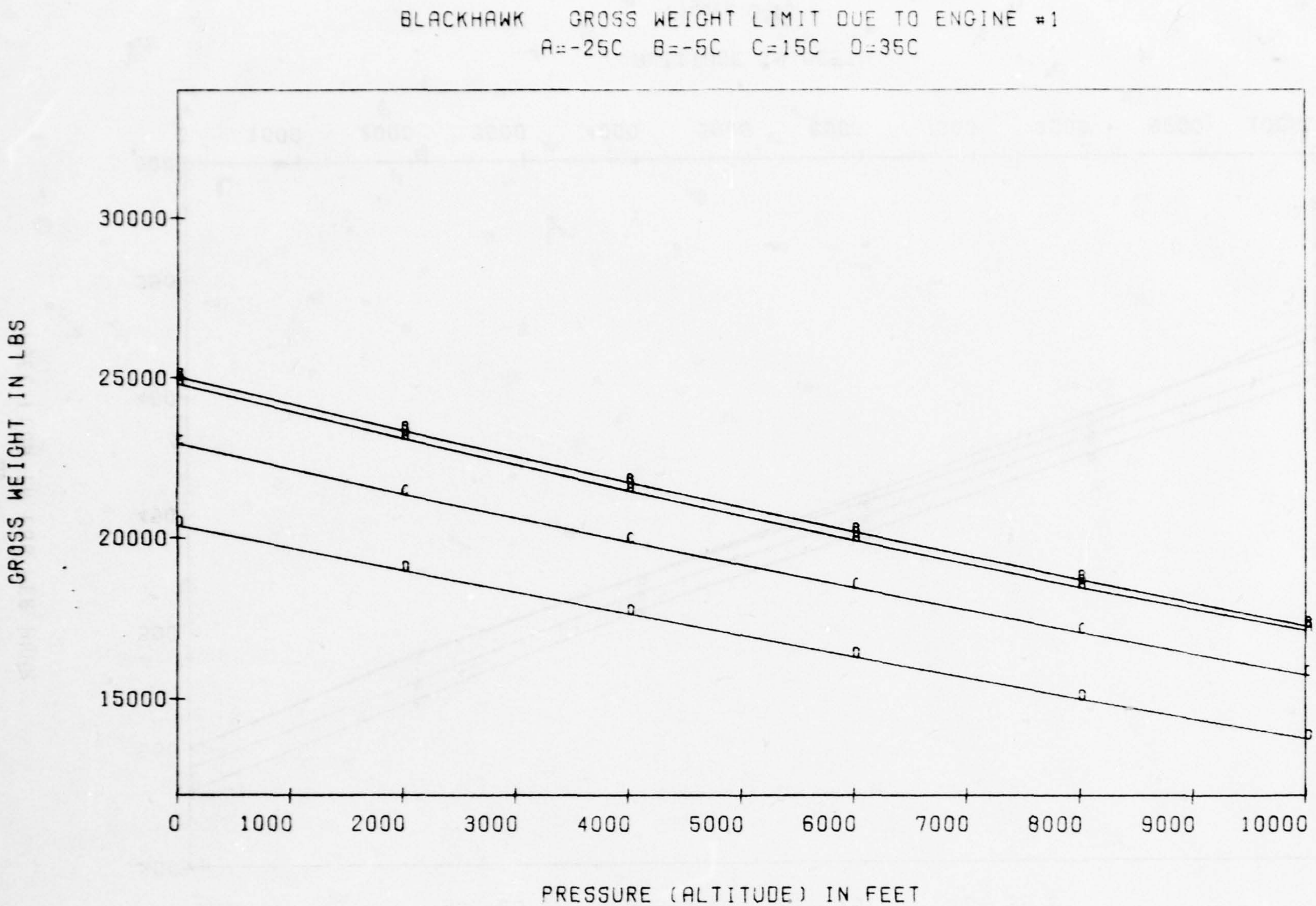

BLACKHAWK GROUND IDLE FUEL FLOW
A= -25 C B= -5 C C= 15 C D= 35 C
FUEL FLOW IN LBS PER HOUR
600
550
500
450
400
350
300
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
ALTITUDE IN FEET

Figure 3-15



BLACKHAWK GROSS WEIGHT LIMIT DUE TO ENGINE #1
A=-25C B=-5C C=15C D=35C
GROSS WEIGHT IN LBS
30000
25000
20000
15000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PRESSURE (ALTITUDE) IN FEET

Figure 3-16

BLACKHAWK   GROSS WEIGHT LIMIT DUE TO TRANSMISSION #1
A=-25C B=-5C C=15C D=35C

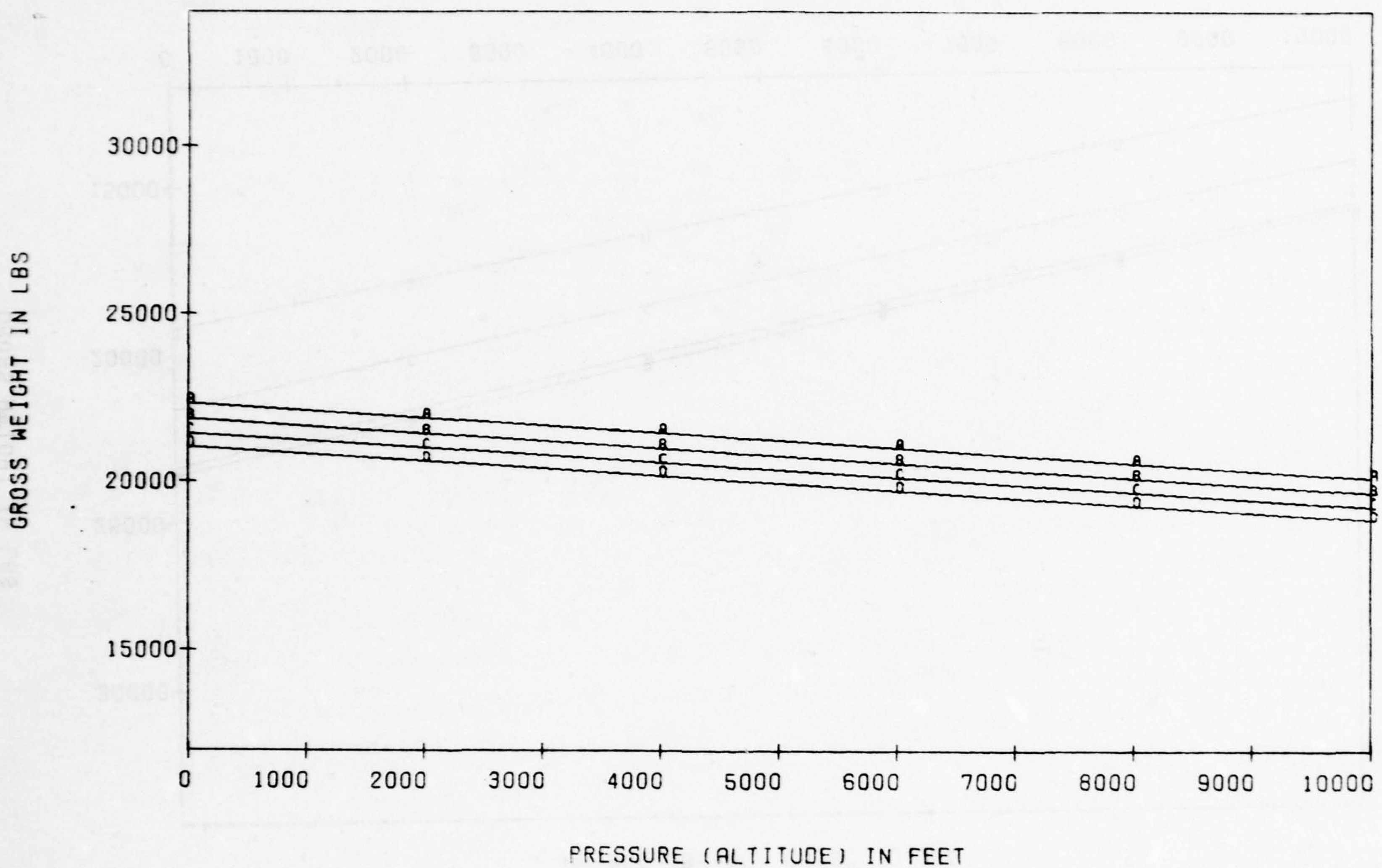


Figure 3-17

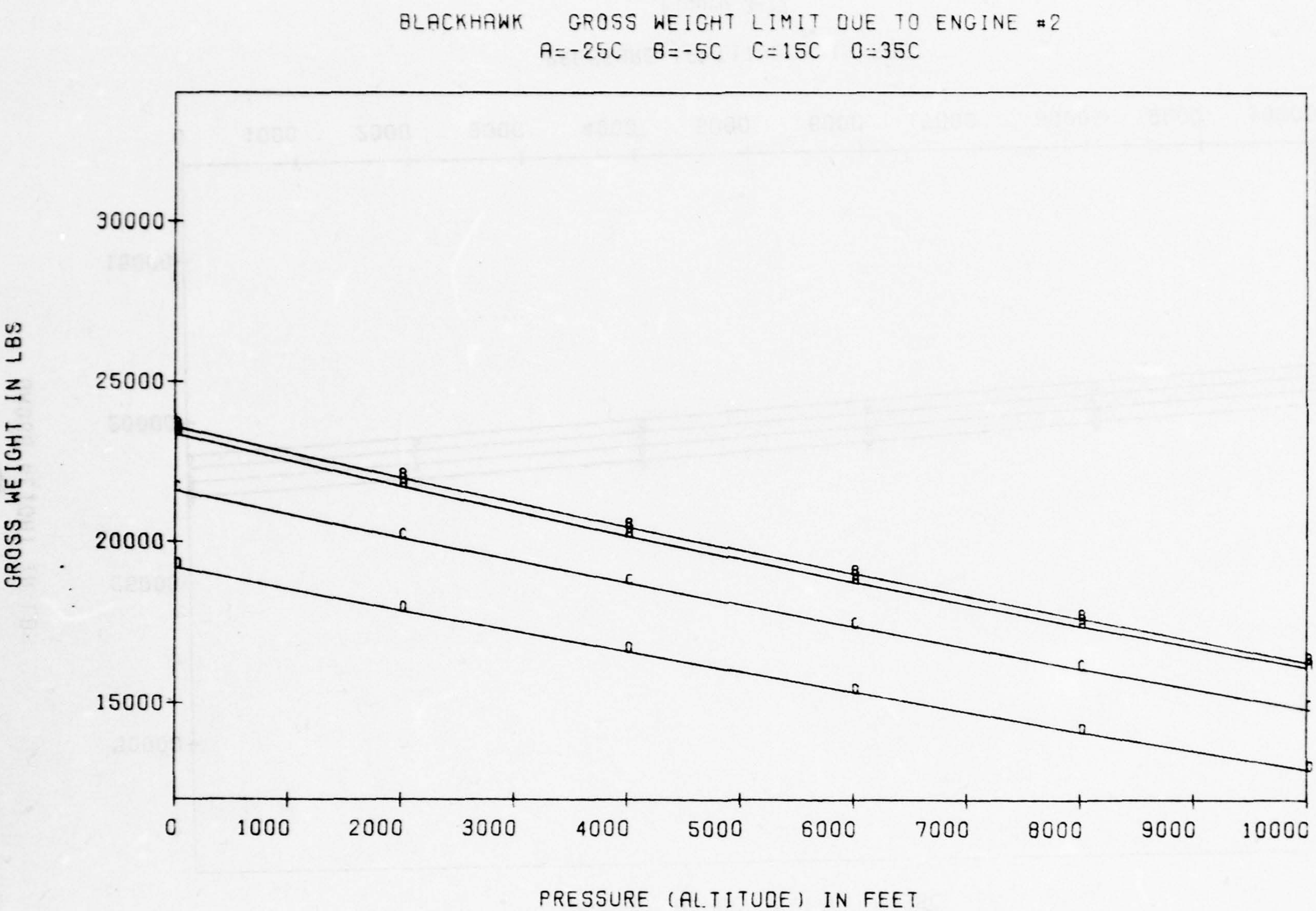

BLACKHAWK GROSS WEIGHT LIMIT DUE TO ENGINE #2
A=-25C B=-5C C=15C D=35C
GROSS WEIGHT IN LBS
30000
25000
20000
15000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PRESSURE (ALTITUDE) IN FEET

Figure 3-18

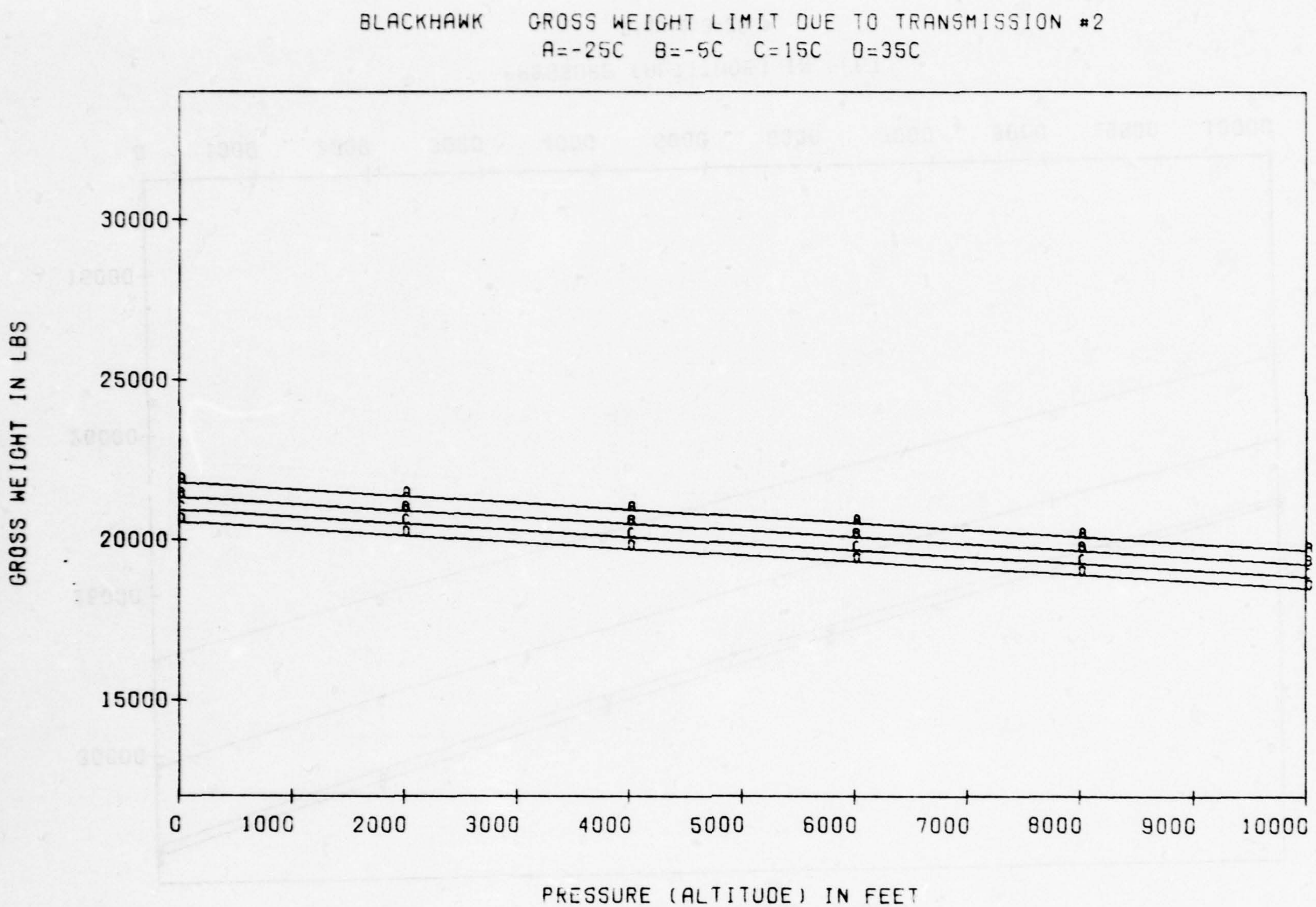

BLACKHAWK GROSS WEIGHT LIMIT DUE TO TRANSMISSION #2
A=-25C B=-5C C=15C D=35C
GROSS WEIGHT IN LBS
30000
25000
20000
15000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PRESSURE (ALTITUDE) IN FEET

Figure 3-19

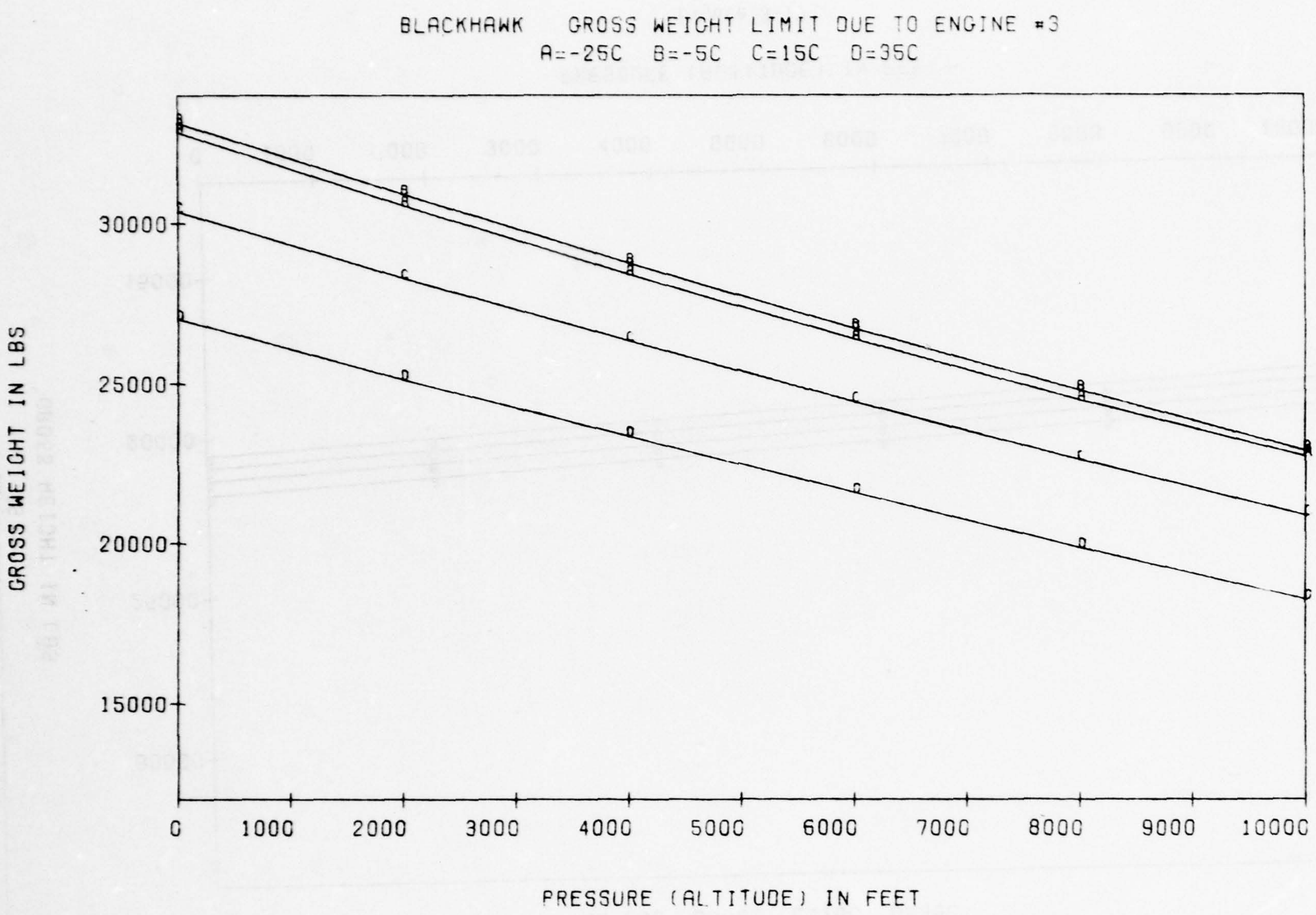

BLACKHAWK GROSS WEIGHT LIMIT DUE TO ENGINE #3
A=-25C B=-5C C=15C D=35C
GROSS WEIGHT IN LBS
30000
25000
20000
15000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PRESSURE (ALTITUDE) IN FEET

Figure 3-20

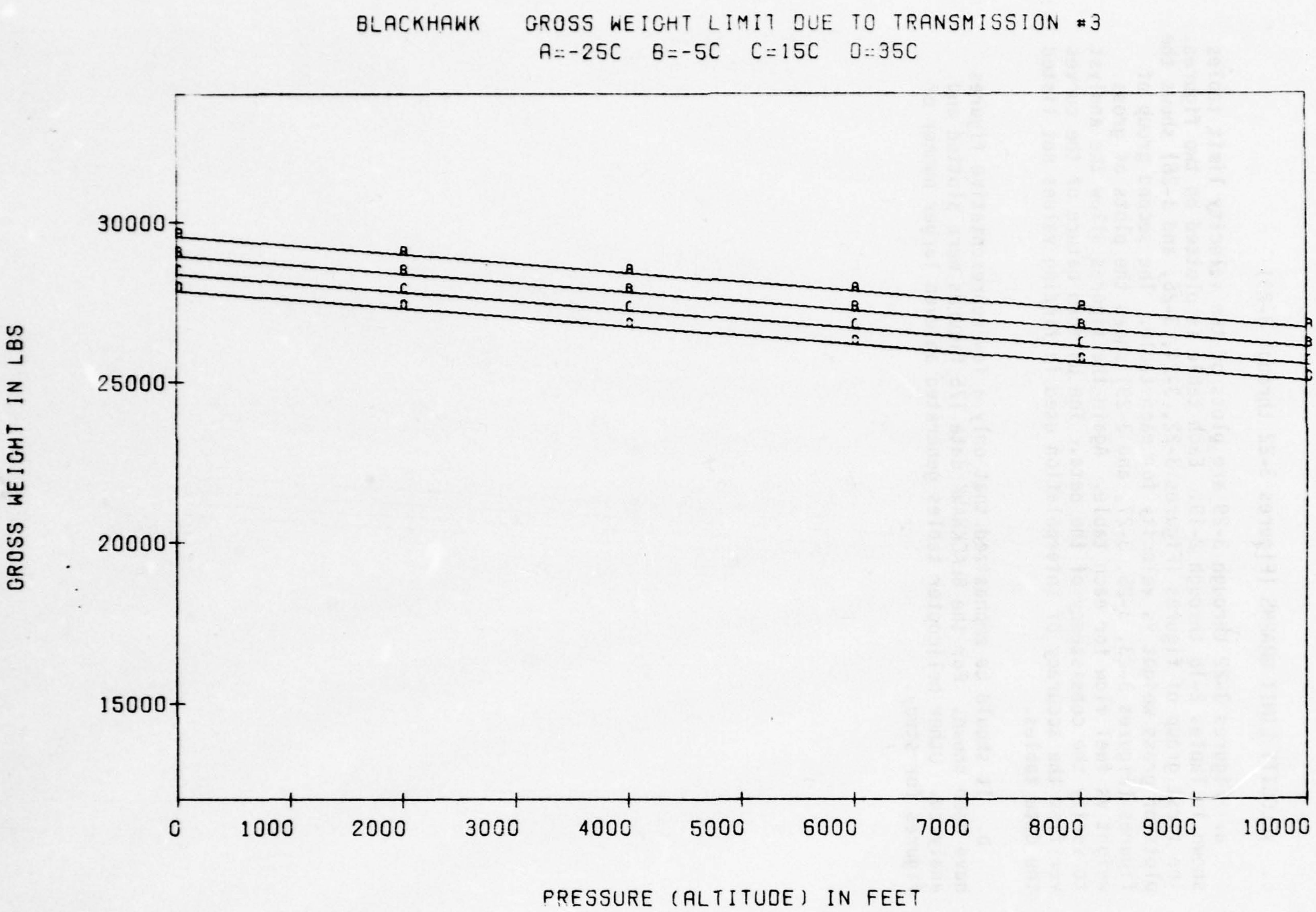

BLACKHAWK GROSS WEIGHT LIMIT DUE TO TRANSMISSION #3
A=-25C B=-5C C=15C D=35C
GROSS WEIGHT IN LBS
30000
25000
20000
15000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PRESSURE (ALTITUDE) IN FEET
A
B
C
D

Figure 3-21

6. VELOCITY LIMIT GRAPHS (Figures 3-22 through 3-29)

a. Figures 3-22 through 3-29 are plots of the velocity limit tables shown in Tables 2-16 through 2-19. Each table is plotted on two figures. The first group of figures (Figures 3-22, 3-24, 3-26, and 3-28) shows the plots of gross weight vs velocity for each table. The second group of figures (Figures 3-23, 3-25, 3-27, and 3-29) shows the plots of gross weight vs fuel flow for each table. Again the figures allow the analyst to verify the consistency of the data. The uniform nature of the curves verifies the accuracy of interpolation used in finding values not listed in the data tables.

b. It should be emphasized that only a few representative figures have been shown. For the BLACKHAWK data 175 figures were plotted and analyzed. Other helicopter tables generated an even larger number of figures for study.

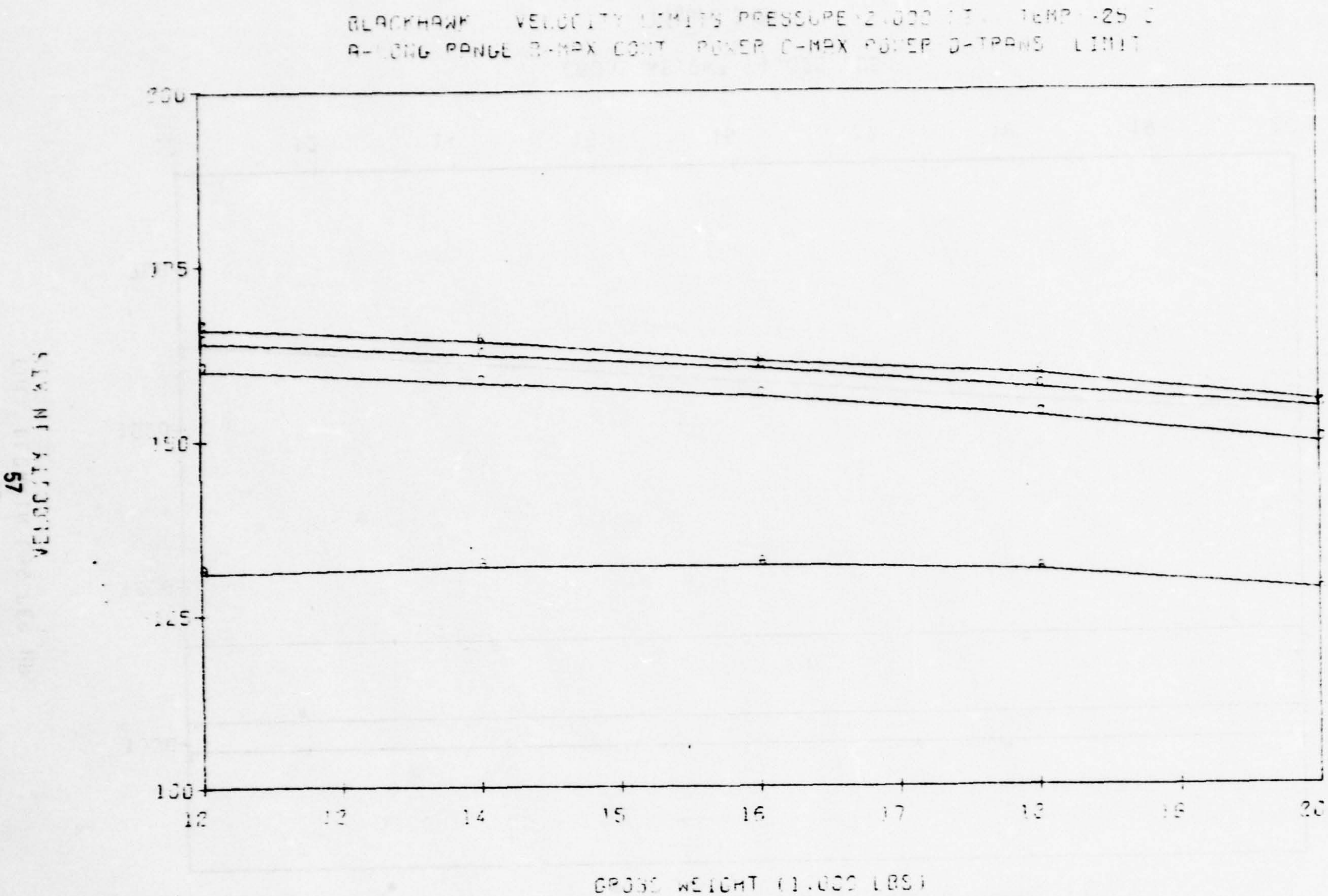

BLACKHAWK VELOCITY LIMITS PRESSURE 2,000 FT. TEMP -25 C
A-LONG RANGE B-MAX CONT POWER C-MAX POWER D-TRANS LIMIT
VELOCITY IN KTS
GROSS WEIGHT (1,000 LBS)
200
175
150
125
100
14
15
16
17
20

Figure 3-22

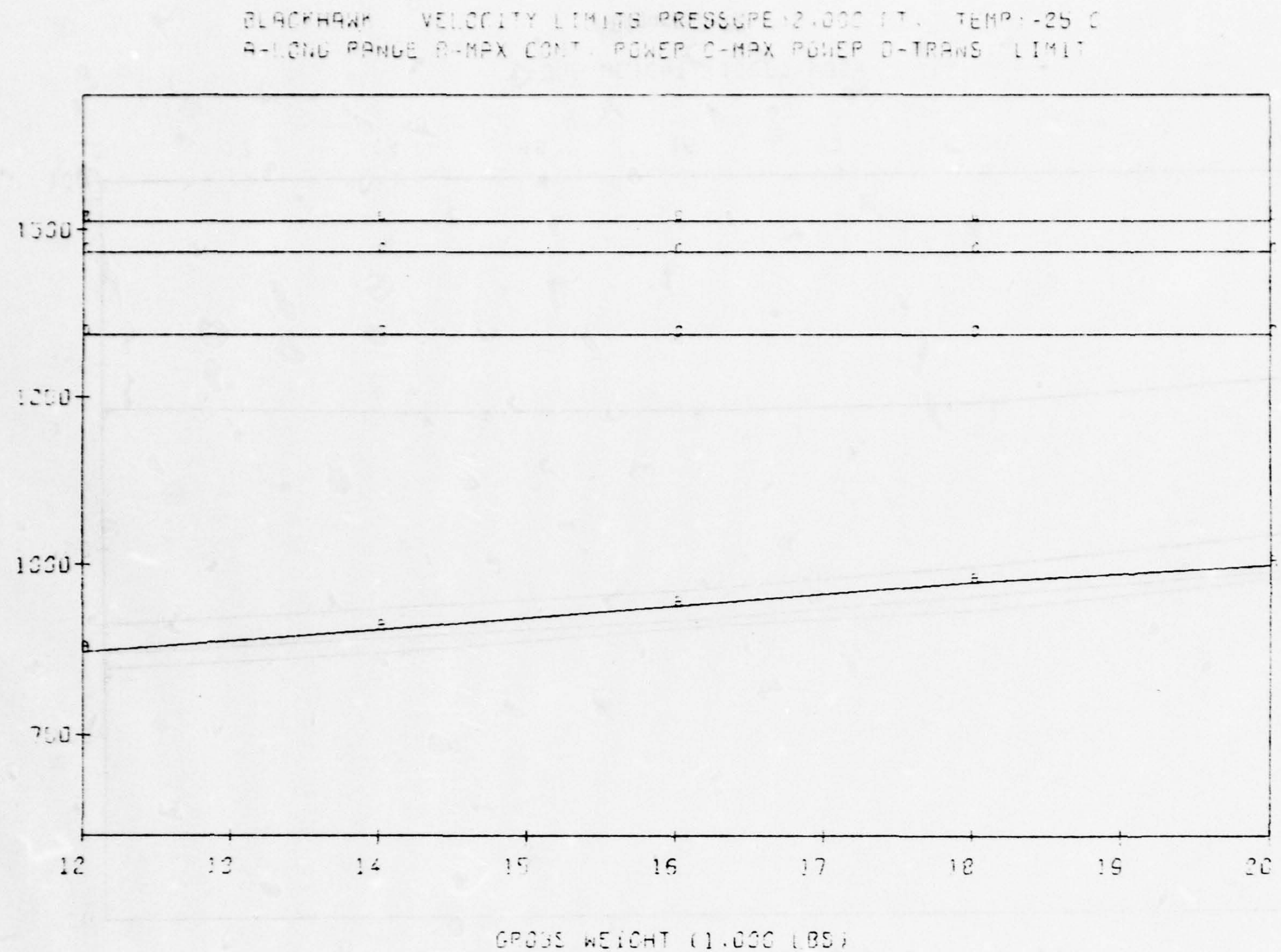
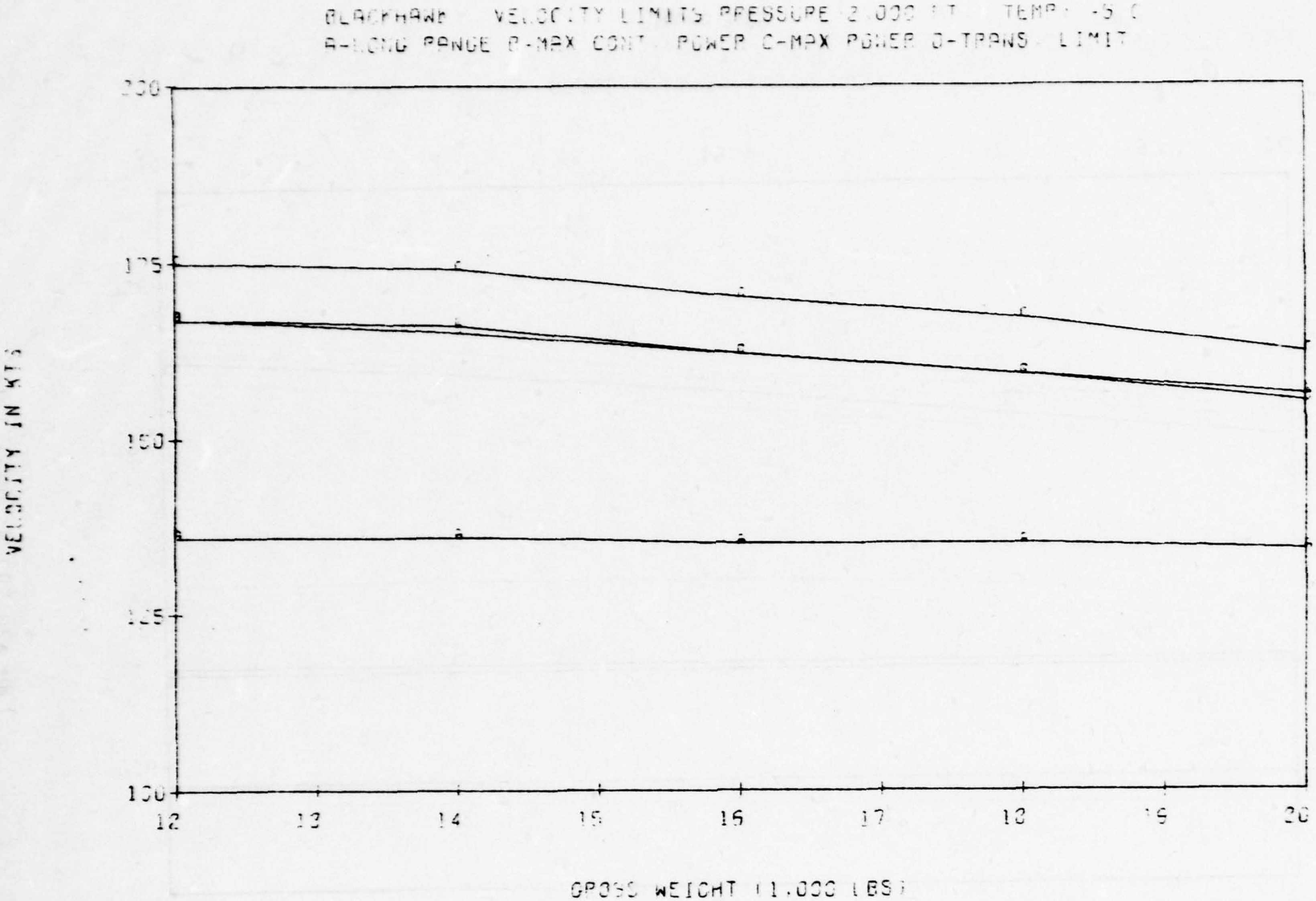

BLACKHAWK VELOCITY LIMITS PRESSURE 2,000 FT. TEMP: -25 C
A-LONG RANGE B-MAX CONT. POWER C-MAX POWER D-TRANS LIMIT
FUEL FLOW IN LBS PER HR
1500
1250
1000
750
12
13
14
15
16
17
18
19
20
GROSS WEIGHT (1,000 LBS)

Figure 3-23



BLACKHAWK VELOCITY LIMITS PRESSURE 2,000 FT TEMP -5 C
A-LONG RANGE B-MAX CONT POWER C-MAX POWER D-TRANS LIMIT
200
175
150
125
100
12
13
14
15
16
17
18
19
20
VELOCITY IN KTS
GROSS WEIGHT (1,000 LBS)

Figure 3-24

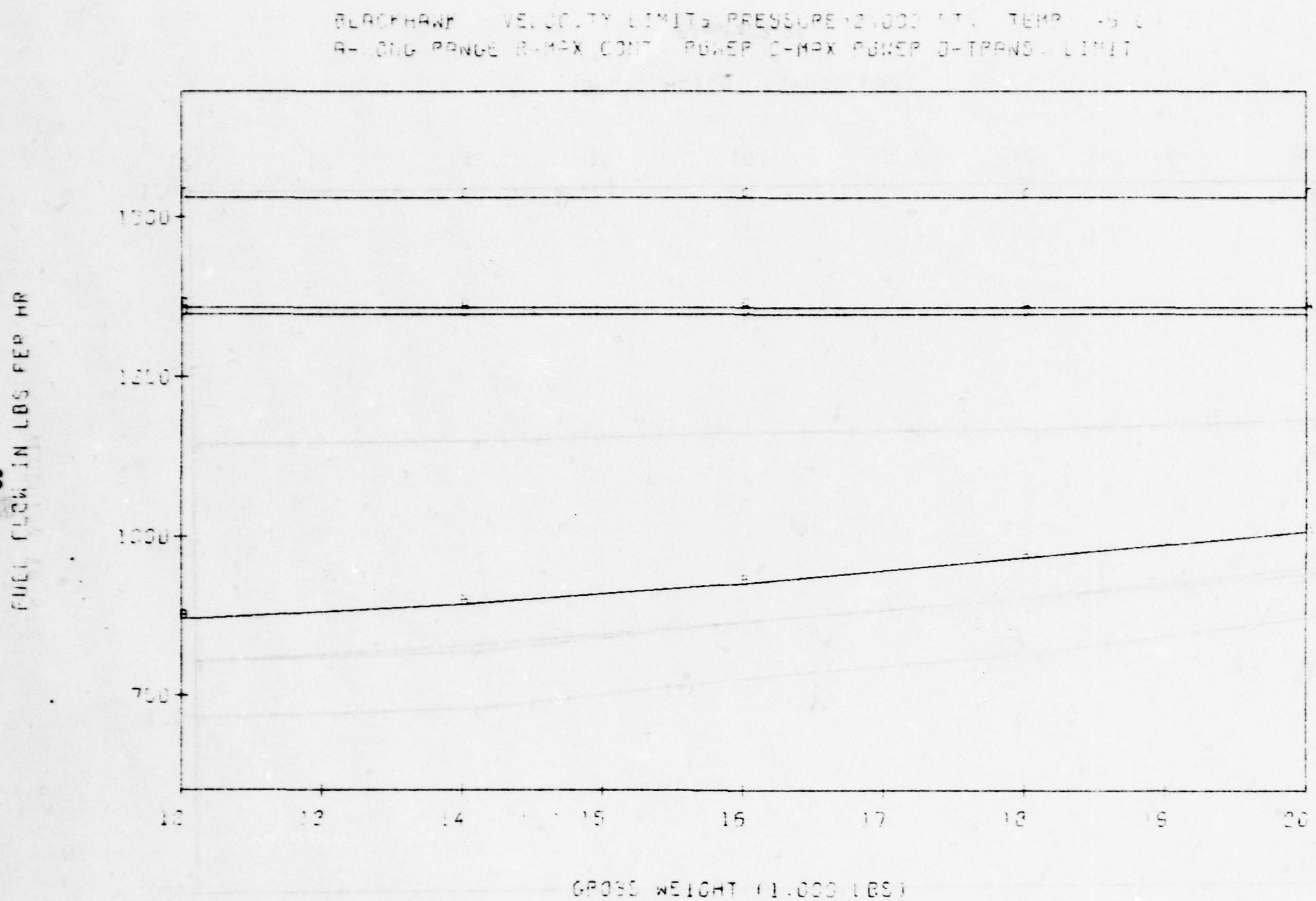

BLACKHAWK VELOCITY LIMITS PRESSURE 2,000 FT. TEMP -5 C
A- LONG RANGE B-MAX CONT. POWER C-MAX POWER D-TRANS. LIMIT
FUEL FLOW IN LBS PER HR
1000
700
12
13
14
15
16
17
18
19
20
GROSS WEIGHT (1,000 LBS)

Figure 3-25

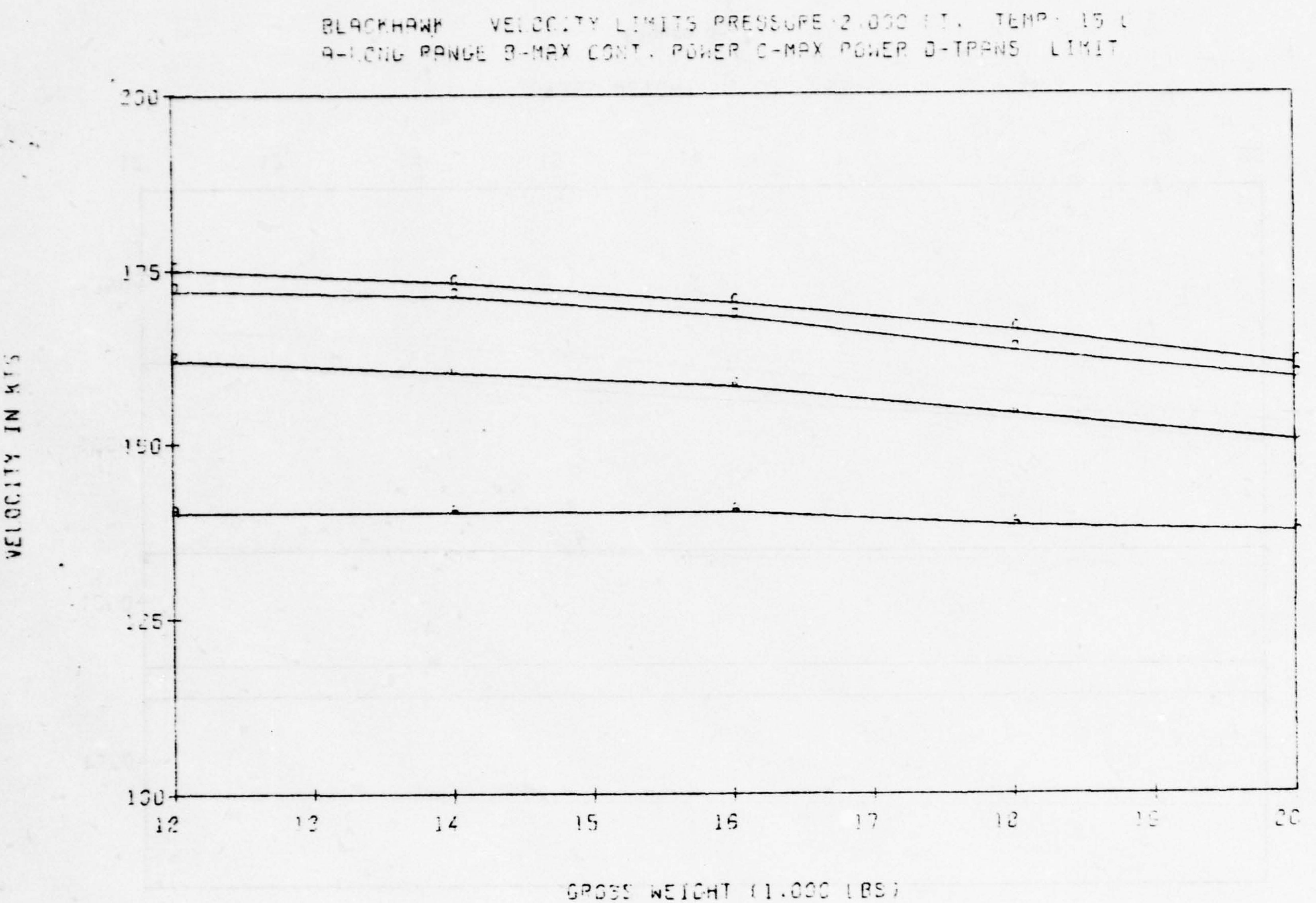

BLACKHAWK VELOCITY LIMITS PRESSURE 2,000 FT. TEMP 15 C
A-LONG RANGE B-MAX CONT. POWER C-MAX POWER D-TRANS LIMIT
VELOCITY IN KTS
200
175
150
125
100
12
13
14
15
16
17
18
19
20
GROSS WEIGHT (1,000 LBS)

Figure 3-26

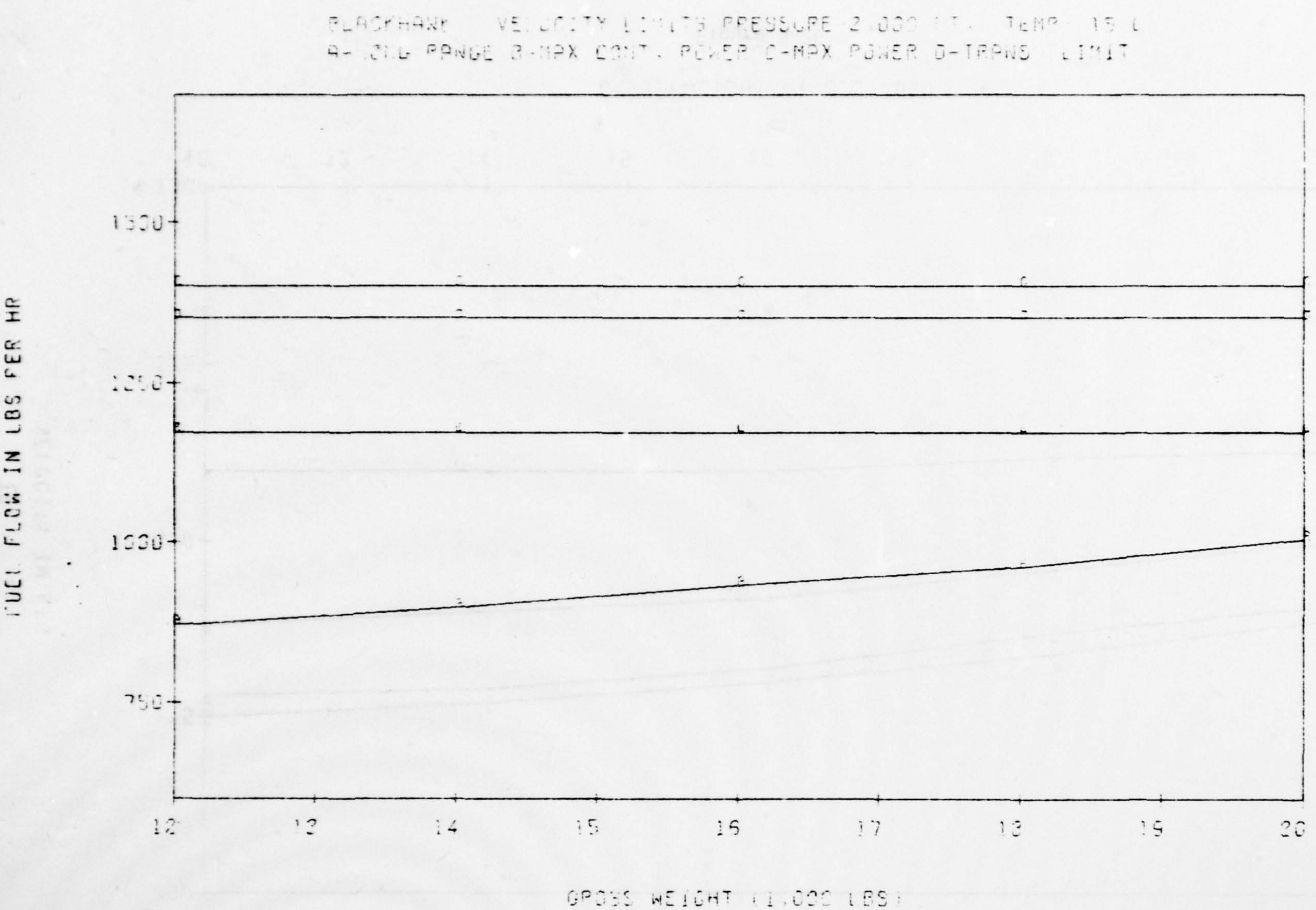

BLACKHAWK VELOCITY LIMITS PRESSURE 2,000 FT. TEMP 15 C
A-LONG RANGE B-MAX CONT. POWER C-MAX POWER D-TRANS LIMIT
1500
1250
1000
750
FUEL FLOW IN LBS PER HR
12
13
14
15
16
17
18
19
20
GROSS WEIGHT (1,000 LBS)

Figure 3-27

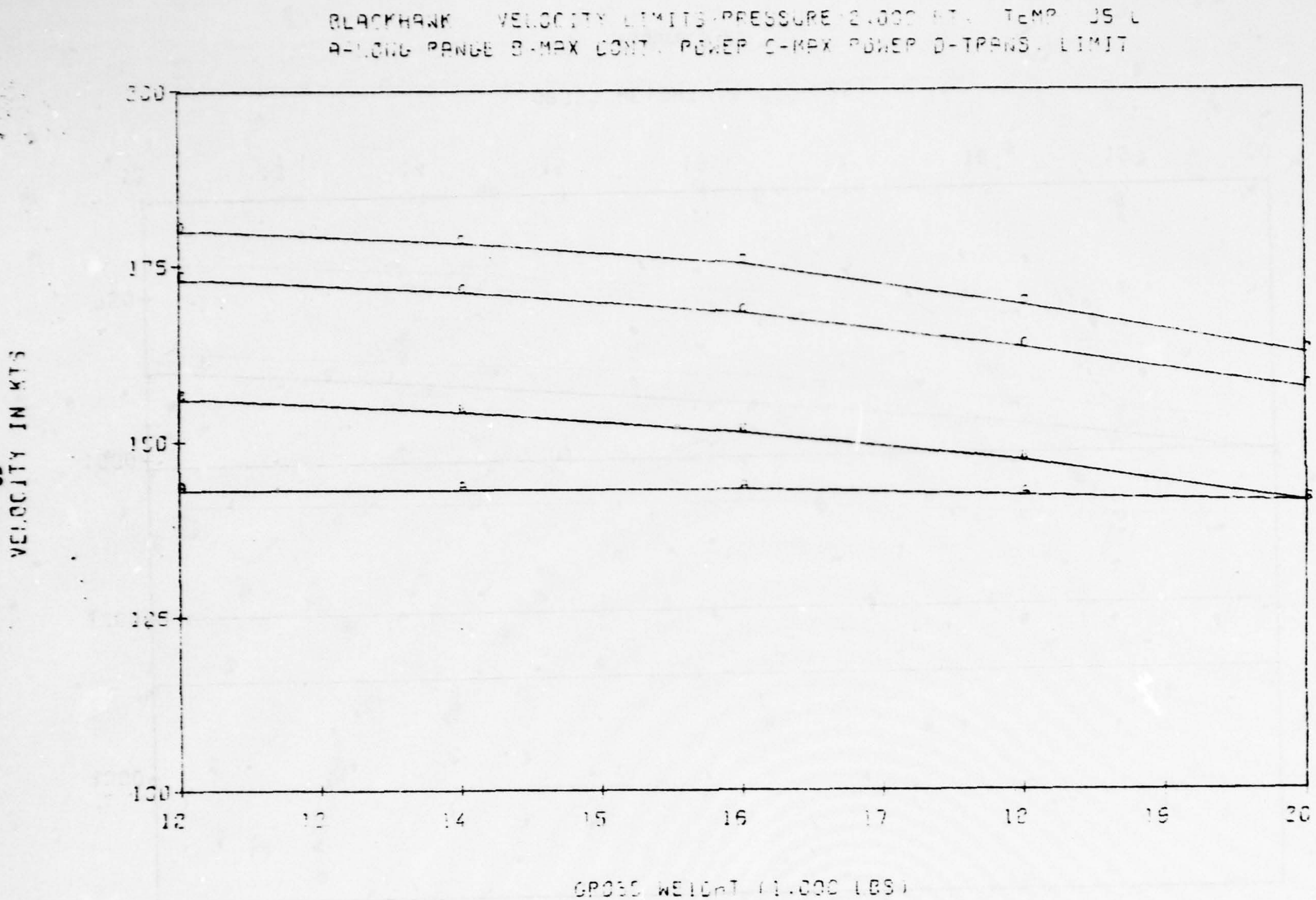

BLACKHAWK VELOCITY LIMITS-PRESSURE 2,000 FT. TEMP 35 C
A-LONG RANGE B-MAX CONT. POWER C-MAX POWER D-TRANS. LIMIT
VELOCITY IN KTS
GROSS WEIGHT (1,000 LBS)

Figure 3-28

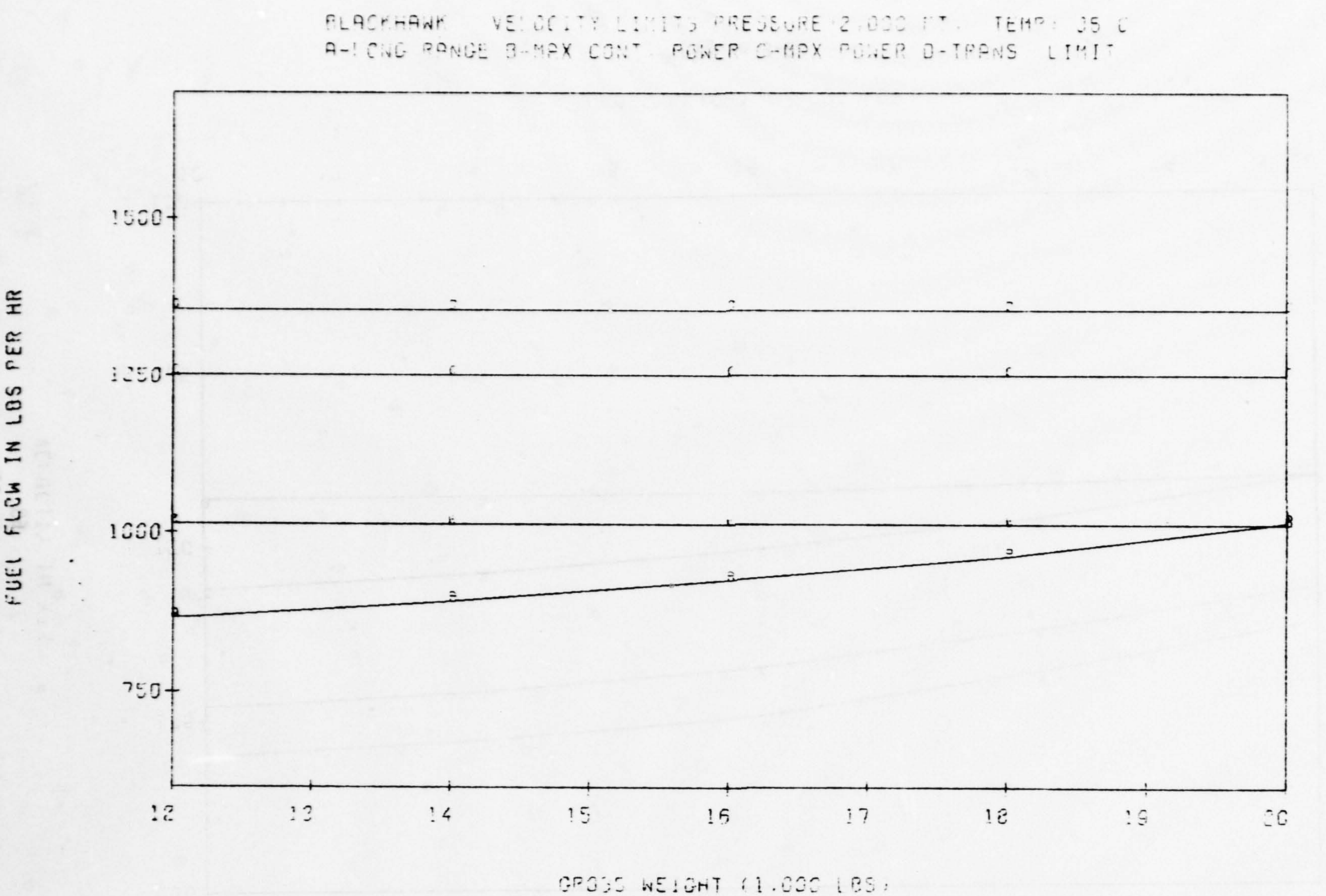

BLACKHAWK VELOCITY LIMITS PRESSURE 2,000 FT. TEMP: 35 C
A-LONG RANGE B-MAX CONT POWER C-MAX POWER D-TRANS LIMIT
1500
1250
1000
750
FUEL FLOW IN LBS PER HR
12
13
14
15
16
17
18
19
20
GROSS WEIGHT (1,000 LBS)

Figure 3-29

CHAPTER 4

METHODOLOGY APPLICATION

GENERATING FLIGHT PROFILES

1. GENERAL

The data tables discussed in Chapter 3 of this handbook can be used to quickly generate an accurate flight profile. The simple profile given as an example in this chapter can be expanded to any degree of complexity.

2. GENERATING FLIGHT PROFILES (Tables 4-1 through 4-10)

a. From mission profile performance tables and experience, assume the following facts about a flight are known:

(1) Type of aircraft: BLACKHAWK

(2) Mission: Fly 6000 lbs of cargo from point A (air base) to point B (drop off area) then return.

(3) Cargo: 2000 lbs of the cargo is an external load that has 25 equivalent square feet of drag.

(4) Altitudes (all given as feet above sea level):

o At A: 2000'

o At B: 1000'

o From A to B: 3000'

o From B to A: 4000'

o Speeds: 60 kts from A to B

120 kts from B to A

(6) Temperature: 15°C

(7) Distance from A to B: 30 nautical miles

(8) Times: o Run-up at A, 10 min

o HIGE to pick up external load, 15 min

o Flight from A to B, 30 min (calculated)

o HIGE to drop external load, 10 min

o Idle at B to unload, 15 min

o Flight from B to A, 15 min (calculated)

o Shut down at A, 5 min

(9) Empty Weight: 12,000 lbs.

b. The flight simulation could be started by drawing up a table similar to Table 4-1. To obtain the entries for Table 4-1, Tables 4-2 through 4-9 are reproduced from the earlier chapters for convenience. With these tables the entries for Table 4-1 are obtained as follows:

(1) Leg #1: Using the ground idle fuel flow (Table 4-7) find the rate for 2000 ft and 15°C. These intersect at 509 lbs/hr. For 10 minutes, 1/6 of an hour:

Fuel = 509 X 1/6 = 85 lbs of fuel

(2) Leg #2: Using the basic fuel flow for 2000 ft and 15°C (Table 4-3), find the rate for HIGE and 16,000 lbs. These intersect at 800 lbs/hr. For 15 minutes, 1/4 of an hour:

Fuel = 800 X 1/4 = 200 lbs of fuel

(3) Leg #3: Since there is no basic fuel flow table for 3000 ft and 15°C, the tables for 2000 ft at 15°C (Table 4-3) and 4000 ft at 15°C (Table 4-4) are used to find values for 2000 ft, 15°C, 60 kts and 18,000 lbs (which is 764 lbs/hr) and 4000 ft, 15°C, 60 kts and 18,000 lbs (which is 745 lbs/hr). By interpolation, the basic fuel flow for 3000 ft, 15°C, 60 kts and 18,000 lbs is 755 lbs/hr.

(4) Similarly two drag tables must be used. The value for 2000 ft, 15°C, 60 kts and 25 sq ft of drag (Table 4-5) is 16 lbs/hr and the value for 4000 ft, 15°C, 60 kts and 25 sq ft of drag (Table 4-6) is 15 lbs/hr. By interpolation the correction for drag for 3000 ft, 15°C, 60 kts and 25 sq ft is 16 lbs/hr. This is added to the basic fuel flow of 755 lbs/hr to give the fuel flow rate for Leg #3, i.e., 755 + 16 = 771 lbs/hr. For 30 minutes of flight, 1/2 of an hour:

Fuel = 771 X 1/2 = 386 lbs of fuel

(5) Since there is a 60 kt airspeed for Leg #3, the velocity limits of the A/C should be checked. Using Tables 4-8 and 4-9 shows the 60 kts is well within the various limits of the A/C.

(6) Leg #4: To calculate a hover at 1000 ft and 15°C, Tables 4-2 and 4-3 must be used for interpolation. Table 4-2 gives a value of 889 lbs/hr for HIGE, 0 ft, 15°C at 18,000 lbs. Table 4-3 gives a value of 875 lbs/hr for HIGE, 2000 ft, 15°C at 18,000 lbs. Interpolation gives a value of 882 lbs/hr for HIGE, 1000 ft. 15°C, at 18,000 lbs. For 10 min, 1/6 of an hour:

Fuel = 882 X 1/6 = 147 lbs of fuel

(7) Leg #5: The idle fuel flow rate at 1000 ft. 15°C is the interpolation of the values for 0 ft at 15°C and 2000 ft at 15°C. These values from Table 4-7 are 549 lbs/hr and 509 lbs/hr respectively. The interpolation value is 529 lbs/hr. For 15 minutes, 1/4 of an hour:

Fuel = 529 X 1/4 = 132 lbs of fuel

(8) Leg #6: The value for fuel flow for 120 kts. 12,000 lbs, 4000 ft and 15°C can be looked up directly in Table 4-4. The value where 12,000 lbs and 120 kts intersect is 706 lbs/hr. For 15 minutes, 1/4 of an hour:

Fuel = 706 X 1/4 = 177 lbs of fuel

(9) Also using Table 4-9 shows the airspeed of 120 kts does not exceed any limits of the aircraft.

(10) Leg #7: The idle fuel flow rate at 2000 ft at 15°C is in Table 4-7. The value is 509 lbs/hr. For 5 minutes, 1/12 of an hour:

Fuel = 509 X 1/12 = 42 lbs of fuel

(11) Having found the values Table 4-1 can be filled in as shown in Table 4-10. A total of 1169 lbs of fuel will be used on the flight. No velocity limits will be exceeded.

TABLE 4-1

SAMPLE FLIGHT PROFILE

Helicopter: BLACKHAWK

Temperature: 15°C

#	LEG	DISTANCE (N.M.)	TIME (MIN)	AS (KTS)	DRAG (SQ FT)	ALTITUDE (FT)	G.W. (LBS)	VEL. LIMITS (KTS)	FUEL (LBS)
1	Idle at A	-	10	-	-	2000	16000	-	
2	HIGE at A	-	15	-	-	2000	16000	-	
3	A to B	30	30	60	25	3000	18000		
4	HIGE at B	-	10	-	-	1000	18000	-	
5	Idle at B	-	15	-	-	1000	16000	-	
6	B to A	30	15	120	-	4000	12000		
7	Idle at A	-	5	-	-	2000	12000	-	
								TOTAL	

TABLE 4-2

BASIC FUEL FLOW

FUEL FLOW RATES FOR THE GIVEN CONDITIONS IN LBS/HR

PRESSURE: SEA LEVEL TEMPERATURE: 15 C

AIRCRAFT - UH-60A
BLACKHAWK

GROSS WEIGHTS (LBS)	FLIGHT MODE (KTS)									
	HIGE	HOGE	NOE	40	60	80	100	120	140	160
12,000	694	818	751	684	652	662	710	797	930	1214
14,000	753	914	824	733	690	693	736	819	952	1238
16,000	818	1020	904	789	735	726	767	847	984	1276
18,000	889	1133	993	854	785	765	804	883	1025	1331
20,000	967	1262	1096	929	839	811	846	922	1071	1405

TABLE 4-3

BASIC FUEL FLOW

FUEL FLOW RATES FOR THE GIVEN CONDITIONS IN LBS/HR

PRESSURE: 2000 FT TEMPERATURE: 15 C

AIRCRAFT - UH-60A BLACKHAWK

GROSS WEIGHTS (LBS)	FLIGHT MODE (KTS)									
	HIGE	HOGE	NOE	40	60	80	100	120	140	160
12,000	669	800	728	656	622	628	670	750	873	1137
14,000	731	901	805	708	663	660	699	774	899	1168
16,000	800	1010	890	769	711	696	733	807	937	1215
18,000	875	1133	987	840	764	739	773	845	982	1281
20,000	957	1275	1099	923	820	790	820	891	1039	1388

TABLE 4-4

BASIC FUEL FLOW

FUEL FLOW RATES FOR THE GIVEN CONDITIONS IN LBS/HR

PRESSURE: 4000 FT   TEMPERATURE: 15 C

AIRCRAFT - UH-60A
BLACKHAWK

GROSS WEIGHTS (LBS)	FLIGHT MODE (KTS)									
	HIGE	HOGE	NOE	40	60	80	1nn	120	14n	160
12,000	647	785	708	631	594	597	634	706	821	1067
14,000	713	891	789	687	639	631	666	735	852	1106
16,000	785	1006	880	753	690	670	703	771	895	1164
18,000	865	1141	987	832	745	718	747	813	946	1252
20,000	951	1297	1111	925	809	774	8n1	872	1022	1407

TABLE 4-5

CORRECTION FUEL FLOW LBS/HR FOR EXTERNAL DRAG

PRESSURE: 2000 FT TEMPERATURE: 15 C

AIRCRAFT - UH-60A
BLACKHAWK

DRAG IN SQUARE FEET	AIR SPEED IN KTS						
	40	60	80	100	120	140	160
25	5	16	39	78	142	239	422
36	7	24	56	114	206	352	636
54	11	35	85	173	315	555	1063

TABLE 4-6

CORRECTION FUEL FLOW LBS/HR FOR EXTERNAL DRAG

PRESSURE: 4000 FT TEMPERATURE: 15 C

AIRCRAFT - UH-60A
BLACKHAWK

DRAG IN SQUARE FEET		AIR SPEED IN KTS						
		40	60	80	100	120	140	160
	25	5	15	36	73	132	223	394
	36	7	22	53	106	192	329	595
	54	10	33	80	161	294	518	995

TABLE 4-7

GROUND IDLE FUEL FLOW

AIRCRAFT - UH-60A

BLACKHAWK

		PRESSURE ALTITUDE (FT)					
		SEA LEVEL	2000	4000	6000	8000	10000
TEMPERATURE DEGREES CENTIGRADE	-25 C	567	529	491	459	426	395
	-5 C	557	521	484	452	419	388
	15 C	549	509	477	446	414	372
	35 C	549	510	477	443	409	378

ENTRIES ARE AIRCRAFT FUEL FLOW RATES IN LBS/HR

TABLE 4-8

VELOCITY LIMITS TABLE

(INCLUDING FUEL FLOW RATES)

PRESSURE: 2000 FT TEMPERATURE: 15 C

AIRCRAFT - UH-60A BLACKHAWK

GROSS WEIGHTS (LBS)	LONG RANGE		MAX CONTINUOUS POWER		MAX POWER (ENGINE)		TRANSMISSION LIMITS	
	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)
12,000	140	872	162	1174	175	1403	172	1351
14,000	140	900	160	1174	173	1403	171	1351
16,000	140	935	158	1174	170	1403	168	1351
18,000	138	964	154	1174	166	1403	163	1351
20,000	137	1007	150	1174	161	1403	159	1351

TABLE 4-9

VELOCITY LIMITS TABLE

(INCLUDING FUEL FLOW RATES)

PRESSURE: 4000 FT   TEMPERATURE: 15 C

AIRCRAFT - UH-60A BLACKHAWK

GROSS WEIGHTS (LBS)	LONG RANGE		MAX CONTINUOUS POWER		MAX POWER (ENGINE)		TRANSMISSION LIMITS	
	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)	VEL (KTS)	F.F. (LBS/HR)
12,000	140	821	161	1089	175	1309	177	1343
14,000	140	854	159	1089	172	1309	174	1343
16,000	139	887	156	1089	168	1309	170	1343
18,000	137	921	151	1089	162	1309	164	1343
20,000	135	980	145	1089	156	1309	158	1343

TABLE 4-10

SAMPLE FLIGHT PROFILE

Helicopter: BLACKHAWK

Temperature: 15°C

#	LEG	DISTANCE (N.M.)	TIME (MIN)	AS (KTS)	DRAG (SQ FT)	ALTITUDE (FT)	G.W. (LBS)	VEL. LIMITS (KTS)	FUEL (LBS)
1	Idle at A	-	10	-	-	2000	16000	-	85
2	HIGE at A	-	15	-	-	2000	16000	-	200
3	A to B	30	30	60	25	3000	18000	OK	386
4	HIGE at B	-	10	-	-	1000	18000	-	147
5	Idle at B	-	15	-	-	1000	16000	-	132
6	B to A	30	15	120	-	4000	12000	OK	177
7	Idle at A	-	5	-	-	2000	12000	-	42
								TOTAL	1169

CHAPTER 5

METHODOLOGY IMPROVEMENTS

FUNCTIONAL USAGE

1. BACKGROUND

The example in Chapter 4 shows that even a short and simple flight profile requires numerous look-ups and interpolations. In the AMPS model mentioned in the introduction this is done by a computer as part of three subroutines of AMPS. But even in such a model the procedure is time consuming. A method of functionalizing the large data base would be useful.

2. BASIC FUEL FLOW

a. A functional set for the basic fuel flow data has been developed. Each volume of the handbook will contain the functions for that particular A/C, with its constants and degree of accuracy. In general, four functions can be used to replace the entire set of basic fuel flow tables for each helicopter. These four general functions are:

FF (HIGE) = f (GW, TEMP, ALT)

FF (HOGE) = f (GW, TEMP, ALT)

FF (NOE) = f (GW, TEMP, ALT)

FF (Forward Flight) = f (AS, GW, TEMP, ALT)

Where FF = Fuel Flow, GW = Gross Weight, TEMP = Temperature, ALT = Altitude, and AS = Air Speed.

b. The three general functions for HIGE, HOGE, and NOE fuel flow are of exactly the same form with the only difference being the constants of each of the terms of the equation. The general function for Forward Flight has nineteen terms plus a constant.

c. These general functions provide a high degree of accuracy. Over the whole range of helicopters the lowest degree of accuracy is about 95% while better than half of them produce 99% accuracy.

3. DELTA FUEL FLOW FOR DRAG

a. The entire set for delta fuel flow for drag tables can be replaced by one function for each helicopter. The general function is of the form:

$$\Delta FF = f \text{ (AS, TEMP, ALT, SQ)}$$

Where ΔFF = Delta Fuel Flow for Drag, AS = Air Speed, TEMP = Temperature, ALT = Altitude, and SQ = Square Feet of Drag.

b. The general function for ΔFF has nineteen terms plus a constant. These functions produce an accuracy of 95% or better.

4. GROUND IDLE FUEL FLOW

a. Each helicopter's ground idle fuel flow rate can be calculated by a single function. The general form of this equation is:

$$GDIDLE = f\ (ALT,\ TEMP)$$

Where GDIDLE - Ground Idle Fuel Flow, ALT = Altitude, and TEMP = Temperature.

b. These functions produce accuracy of 98% or better.

5. GROSS WEIGHT LIMITS FOR TAKEOFF

a. Six functions are needed to replace each helicopter's set of gross weight limits for takeoff. Each of the six functions is of the same form:

$$GW = f\ (ALT,\ TEMP)$$

Where GW = Gross Weight Limit, ALT = Altitude, and TEMP = Temperature.

b. The only difference in the functions is the value of the constants change from function to function. These functions produce accuracies of 95% or better.

6. FUTURE DEVELOPMENT

The future looks promising for replacing the velocity limits tables by a small number of functions. Also it may be possible to have a smaller number of functions to calculate gross weight limits for takeoffs. As additional functions are generated they will be incorporated into future revisions of the Flight Profile Performance Handbook.